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ABSTRACT

Conference proceedings from this national symposium on hard scientific research and developments in teaching tennis, squash, racquetball, and badminton are divided into several sections. The first deals with sports medicine and the biomechanics of the racquet sports. The second part discusses the pyschological and sociological aspects of competitition and participation in these sports, with particular emphasis on the difference between males and females. A third section deals with physiology, as well as with sports medicine and biomechanics, and the fourth considers motor learning and teaching strategies. Other topics treated in the proceedings include the analysis of stroke production through cinematic means, the development of various instructional aids, and a dynamic test for the comparison of rebound characteristics of three different brands of tennis ball. An evaluation of the symposium by participants is included. (LH)

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PROCEEDINGS OF A NATIONAL SYMPOSIUM ON

The Racquet Sports

An Exploration of Research Implications and Teaching Strategies

June 13–16, 1979

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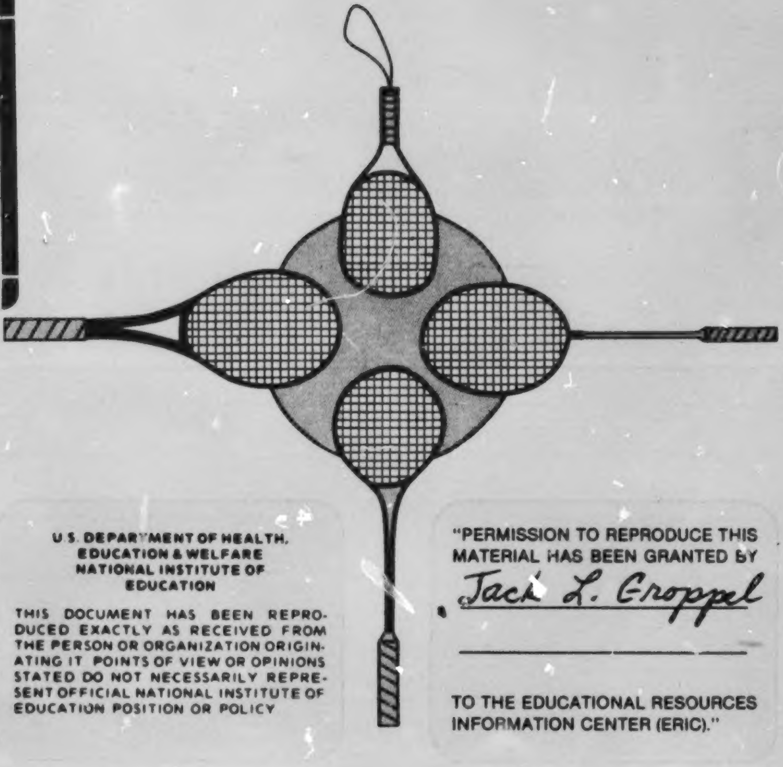

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ACKNOWLEDGEMENTS

Since this symposium was one of the first of it's type to be held in the United States, the time spent in organization and administration was phenomenal. Without the neverending diligence and support of many individuals, a project of this type could never have been undertaken. Of utmost importance among this group was Ronald G. Sears from the Office of Conferences and Institutes who helped coordinate the symposium.

Special thanks should be extended to Sports Foundations, Incorporated for the generous grant donated to help curtail the costs of such a conference. Through this funding and the support of Dr. Kenneth S. Clarke (Dean, College of Applied Life Studies) and Dr. Rollin G. Wright (Head, Department of Physical Education), the accomplishments of this meeting were facilitated.

The following individuals should also be commended for their assistance and advice in organizing and conducting this symposium: John Avallone, Kevin Campbell, John Carlson, Charles Dillman, Michael Dunetts, Mark Hahn, Daniel India, E. Keith Milner, Karl Newell, Ladd Pash, Linda Pecore, Fontaine Piper, Glyn Roberts, Kathy Schroeder, Mary Slaughter, Terry Ward and John Wilson.

Sincere appreciation is also given to the staff of the Office of Conferences and Institutes who provided the necessary guidance and many hours that go into a symposium of this type. Special thanks is extended to the secretaries who devoted a great deal of time to typing the edited manuscripts for this Proceedings: Terry Bodecker, Laurie Mitchell, Mary Nelson and Barbara Young. Finally, I would like to credit Randall C. Pregler with the excellent photography seen within this publication.

Jack L. Groppel, Ph.D.
Symposium Coordinator

PREFACE

It is evident to most people who enjoy physical activity that the racquet sports have had a noted societal effect over the past few years. Millions of men, women and children have thronged to the court for exercise, fitness improvement, competition, general recreation and a multitude of other reasons.

With the sudden increase in enthusiasm for the racquet sports, skilled instructors are necessary to teach correct movement patterns. This instruction can range from a very concise, mechanical approach of teaching, to a psychological approach, where mechanics are not even discussed. In fact, it is possible that during a discussion between ten teaching pros of a certain racquet sport, one might hear ten different instructional methods for one stroking movement. This places the novice, intermediate and often the skilled performer, in a precarious situation attempting to determine which instructional strategy to follow.

Who determines which method within a continuum of teaching ideas is most effective? Only carefully controlled and applied research can inform the player and coach which instructional concept or concepts might be better for a specific stroking movement.

Research on the racquet sports has been conducted throughout the country on all aspects of each activity, but there has never existed any consistent means by which this research could be collected, interpreted for the practitioner, and disseminated to players and coaches. For this reason, the University of Illinois College of Applied Life Studies recently hosted the first"National Symposium on the Racquet Sports" on June 13-16, 1979. The purpose of this conference was not only to provide the practitioner with innovative methods of performing but also to inform racquet sport enthusiasts of: 1) current conditioning and warm-up techniques, 2) how to detect movement errors more effectively, 3) how the racquet sports can be used as therapeutical aids, and 4) implications involving injuries and other sports medicine topics in the racquet sports.

Approximately 100 individuals from the United States, Canada and Japan attended the symposium. These participants consisted of about 60% sport scientists and 40% coaches and/or players. The focus was to provide for interaction between these two previously unacquainted groups. Four racquet sports were represented: badminton, racquetball, tennis and squash. Some of the most noted authorities in the world were present to give instructional clinics in each of the four activities. Instructional guest speakers included David B. Waddell (level 3 National badminton coach from Canada), John Lynch (formerly rated #9 in the United States Racquetball Association), Vic Braden, Chet Murphy, and Joan Ramey-Ford for the sport of tennis; David Fish (Harvard Squash coach); and Joanne Taylor (conditioning and nutrition consultant to the Women's Tennis Association). Scientific and sports medicine guest lecturers included Dr. Robert Baller (past-president of the Illinois Association of Ophthalmology); Dr. James Glick (assistant clinical professor for the University of California-Berkeley Department of Orthopedic Surgery); and Dr. Stanley Plagenhoef (Professor of Biomechanics at the University of Massachusetts). In addition to these selected lectures, twenty-five scientific papers were presented by independent researchers. The scientific papers dealt not only with instructional concepts but also with biomechanical. physiological, psychological, sociological and sports medicine problems often encountered in the four racquet sports.

The results of the invited presentations, and all scientific papers were interpreted and shared with those players and coaches in attendance. The participants were then permitted to express their opinions regarding the presented information. There was, as always, concurrence and disagreement with certain teaching philosophies but it was felt that a large step forward was taken by holding this symposium. One very important fact was observed: Both groups, practitioners and sport scientists alike, learned a great deal from each other. The players and coaches gained some practical scientific information regarding their particular activity but, more importantly, they met individuals who could potentially provide them with answers to some of their coaching and/or playing problems in addition to various medical aspects of their sport. In contrast, the researchers learned that some of their work was unnecessary for players and coaches due to it's impracticality or it's degree of sophistication. The practitioners were also able to comment on what type of research was desirable to them and also how it could benefit a player or coach.

A panel discussion was held at the termination of the symposium to discuss what had been achieved, where research in the racquet sports was headed in the future, and whether a symposium of this type should be organized on a regular basis. The panel, composed of several invited speakers, determined that the symposium was successful in that this was the first time in the United States that coaches, competitors, and sport researchers gathered formally to discuss common problems and possible methods of answering those problems.

The interaction that took place during this Racquet Sports Symposium was unprecedented in the United States. It was actually refreshing to see two previously estranged groups of people together attempting to sort out questions and answers that could provide each with better understanding of their particular sport or of racquet sports in general. This type of interaction may be enough reason to consider holding such a conference on an annual basis.

Jack L. Groppel, Ph.D.
Symposium Coordinator
August, 1979

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SPORTS MEDICINE

AND

BIOMECHANICS

QUALITATIVE ANALYSIS OF THE BADMINTON FOREHAND SMASH AS PERFORMED BY INTERNATIONAL PLAYERS[1]

by

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Abstract

The technique of playing overhead power strokes and, in particular, the badminton forehand smash, has been closely scrutinized by Gowtizke and Waddell (1977; 1978). General aspects of the overarm stroke in several racquet sports including badminton have been studied by Adrian and her co-workers (1971; 1978). In general, the research has shown that the elite player employes a marked degree of forearm pronation just prior to contact with the shuttlecock, and combines this, sequentially, with other body lever actions so that, in essence, most of the power emanates from a turning of the upper and lower arm. The results of these studies suggest that the current existing literature (books, periodicals, coaching manuals) is incomplete and incorrect.

The purpose of the present study was to extend the research beyond the confines of the laboratory and to observe international elite players under competitive conditions. Gowitzke and Waddell collaborated with Adrian to cinematographically record techniques employed by world-class athletes at the 1978 Commonwealth Games. Two high speed (Lo-Cam) cameras were operated at speeds up to 200 frames per second during quarter-final and semi-final matches.

The results of subsequent film analysis supported previous findings by the present authors. All elite players hit the forehand smash with power by invoking marked medial rotation of the upper arm at the shoulder joint and pronation of the forearm at the radio-ulnar joints just prior to contact with the shuttlecock. The arm flexed at the elbow immediately preceding contact and no classical wrist snap was employed.

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[1] The authors gratefully acknowledge the assistance of the following people: Mrs. Sally Gadd for her illustrations; Mr. Donald Clayton, Photographic Analysis, for loan of one Lo-Cam camera; Dr. Marlene J. Adrian for her assistance with the cinematography; the Department of Kinanthropology at the University of Ottawa for use of their analysis equipment; and Dr. Juris Terauds and the Commonwealth Games officials for their cooperation during the filming.

The technique of playing overhead power strokes and, in particular, the badminton forehand smash, has been the subject of a series of studies which were initiated by the authors in January 1975. This continuing research is concerned with analyses of badminton strokes as they are played by top-ranked Canadian and international elite players for the following purposes:

1. To identify those motor elements which are employed by elite athletes when playing power strokes.
2. To fashion teaching clues and coaching cues that may be used by the teacher or coach to elicit the motor patterns employed by the elite players.
3. To relate biomechanical principles to the technique of stroke production so that comprehension of the elite player's performance is enhanced, and suggestions for improving the technique of stroke production, perhaps beyond presently possible levels, can be made.

The scope of the research, to date, has included analyses of the overhead clear and smash, for both forehand and backhand strokes as played by top-ranked Canadians (4,13); more recently, the authors have focused their attention on qualitative and some quantitative analyses of the forehand and backhand smash (3,5,12). The present paper is limited to a qualitative analysis of the forehand smash and, unlike previous papers, includes data provided by cinematographic records of international players performing under competitive conditions at the 1978 Commonwealth Games.

Review of the Literature

Although considerable literature, in the form of books, periodicals and coaching manuals, is available on the execution of badminton strokes, most of it appears to have been derived from the writers' personal observations and experiences as coach, teacher and/or player. Little research on badminton has been conducted and what there is covers topics such as the development of practical tests of players' abilities, the results of various methods of teaching badminton skills, construction of a shuttlecock ejector, studies of the effect of air resistance on shuttlecocks, the physical demands of recreational and competitive badminton, and studies of physiological changes, strength, endurance and anxiety levels of the badminton player.

Only a few of the research topics have been concerned with analyses of the strokes. Of these, five included the forehand smash (1,6,7,8,10). Only Poole's dissertation and the study by Adrian and Enberg included the smash as it was played by international caliber players.

Little can be gained by reviewing in detail the views of each of the many authors on basic stroke production. Suffice it to say that, over a forty-year period, there has been little change in the concept that wrist action is the most important component of the total arm action in overhead power strokes, and has been variously termed: "breaking the wrist", "uncock the wrist", "wrist snap" and "the wrist whips through", to mention only a few. The present authors have strongly recommended that "it is an appropriate time to lay to rest the myth of 'wrist snap'. It has plagued the teaching of badminton stroke production too long--the requiem is overdue!" (13).

A provocative article by Rantzmeyer (11) supported the contentions of Poole (9,10) and the results of studies carried out by the present authors. Poole (9) said that "...we rarely 'snap' the wrist", and "all badminton strokes are made with forearm rotation rather than wrist snap. Granted, the wrist will rotate along with the forearm, but not in the classic action as described and shown in some books." Subsequently, Poole (10) gathered evidence which supported his hypotheses by filming international players for his doctoral dissertation.

Johnson and Hartung (7) were interested in Poole's findings and evolved badminton data which compared movement times using the wrist (flexion and extension) and forearm (pronation and supination) actions; they concluded that rotational movements of the forearm resulted in faster movement times than wrist actions. Adrian and Enberg (1) filmed three different sports skills (badminton smash, volleyball serve and tennis serve) as they were performed by nationally-ranked players. They identified humeral outward rotation preceding the visible forward movement of the shoulder and elbow of the badminton player as an important component of the stroke. Several years later, Jack, Adrian and Yoneda (6) used the technique of electrogoniometry to compare wrist and forearm actions of overhead strokes as they were employed in four different racquet sports (tennis serve, badminton smash, racquetball and squash power strokes). No single feature of motor performance distinguished any one sport or player (with the single exception of a national caliber racquetball player), perhaps because the data included movement as early as 0.1 second prior to contact of racquet with projectile and as late as 0.1 second after contact. Their results are not surprising because the present authors have shown that the characteristic features of a badminton stroke, from backswing to follow-through, take place in less than 0.1 second, and can only be revealed when data are sampled and discussed at a frequency of 0.01 second (10 msec) or less (13). Indeed, Jack _et_ _al_.(6), interpreted their results over this "long" interval as showing a preference for movement of only the wrist joint at impact. However, they acknowledged that the level of performance of the players used as subjects was probably not sufficiently high to discern the uniqueness of the wrist and forearm movements specific to any of the four sports.

The present authors concurred with Poole's (9) emphasis on forearm rotation, added their data on upper arm rotation, noted that the elbow flexed immediately preceding contact with the shuttle, and showed that _no_ classical wrist snap was used. The research of the forehand smash has shown that the elite player employed a marked degree of forearm pronation just prior to contact with the shuttlecock, and combined this, sequentially, with other body lever actions so that, in essence, most of the power emanated from a turning of the upper and lower arm. In short, the research findings have shown that the current existing literature is incomplete, and, in most cases, incorrect (4,5,13).

Procedure

The authors collaborated with Adrian to cinematographically record techniques employed by world-class athletes at the 1978 Commonwealth Games. Two high speed (Lo-Cam) cameras were operated at speeds of 100, 150 and 200 frames per second during the championship matches. The cameras, coordinated by hand signal, were placed 90 degrees apart and focused on the same half court of play at the same time.

Parts of 24 matches were recorded on high speed Kodak Ektachrome 7250 film of ASA 400; the film was developed at ASA 1600.

Most of the players photographed were those who reached the quarterfinal and semifinal rounds in all events: mens' and ladies' singles; mens' and ladies' doubles; and mixed doubles. Camera placement was limited to two of the six courts so that "the luck of the draw" determined the players that were recorded on film.

In this paper, 27 forehand smashes performed by 22 players in various events were qualitatively analyzed using film from the camera positioned behind the baseline. The players were: men--Tyrrell (Australia); Carter, Czich, Fabris and Priestman (Canada); Jolly, Stevens Talbot and Tredgett (England); Ganguli and Prakash (India); Moo, Ong and Saw (Malaysia); Purser, R. (New Zealand); and Dawson and Gilliland (Scotland); women--Clarkson and Youngberg (Canada); Webster (England); Ng (Malaysia); and Flockhart (Scotland).

The film was analyzed using a stop-motion analysis projector and a Vanguard analyzer. Although quantitative analysis was not carried out, the placement of x and y coordinates in the Vanguard system facilitated more accurate assessment of movement of parts of the body and racquet in space.

Results

The biomechanics of the badminton smash as performed under laboratory conditions by nationally-ranked Canadians was described by Gowitzke and Waddell (5) and provided a useful reference for analyzing techniques of international elite players performing under competitive conditions. The description and illustrations follow:

Preparatory Phase:

Preliminary movements used by players to move the racquet head into backswing position have been qualitatively analyzed as part of the preparatory phase of the stroke. Generally, all players used some degree of knee and hip flexion of both lower extremities as the racquet was drawn backward. The shoulder of the 'hitting' arm was drawn backward by a combination of lateral rotation at the hip joint of the contralateral* leg and rotation of the trunk and intervertebral joints. The elbow was drawn backward by the same movements and by horizontal extension and abduction of the shoulder joint. The racquet head was circled backward and then downward by a combination of the previously described movements and by lateral rotation of the shoulder joint, supination of the forearm and dorsiflexion and and radial flexion of the wrist joint; the hand stayed in place (in space) as though it were a center of rotation for these movements. When viewed from a position behind the subject, the racquet head was seen to be 'on edge' (Figure 2(a)) while the side view of the racquet head showed the full face of the racquet with the. . . hand above the racquet head (Figure 1(a)). Some degree of trunk hyperextension was evident in most players as they reached the 'end' of the backswing.

Force Producing Phase:

The force producing phase of the stroke in any sports skills is usually described by most authors as that portion of the stroke when all joint actions are in the "hitting" direction. It was difficult to discern a precise point in time when the backswing ended and the forward swing began because the badminton players used a fluid action, sequentially shifting from the backswing or 'wind up' phase to the forward swing or 'unwinding' phase. For example, while the racquet head was still being drawn backward, the lower extremities had started their move forward. First, the trunk was medially rotated over the forward leg at the hip joint as the spinal rotation (intervertebral joints) was still counter-rotating (backward). Then, the spinal rotation reversed and the trunk rotated toward the forward leg while the elbow was still moving backward. Spinal rotation continued as the joints of the upper extremity reached the limits of their ranges so that it gave the impression of the body 'moving out from under the arm' with the hand staying almost motionless in space behind the head.

*Contralateral means the opposite side or literally, the body part on the opposite side from the racquet hand. The converse of this, ipsilateral, means the same side

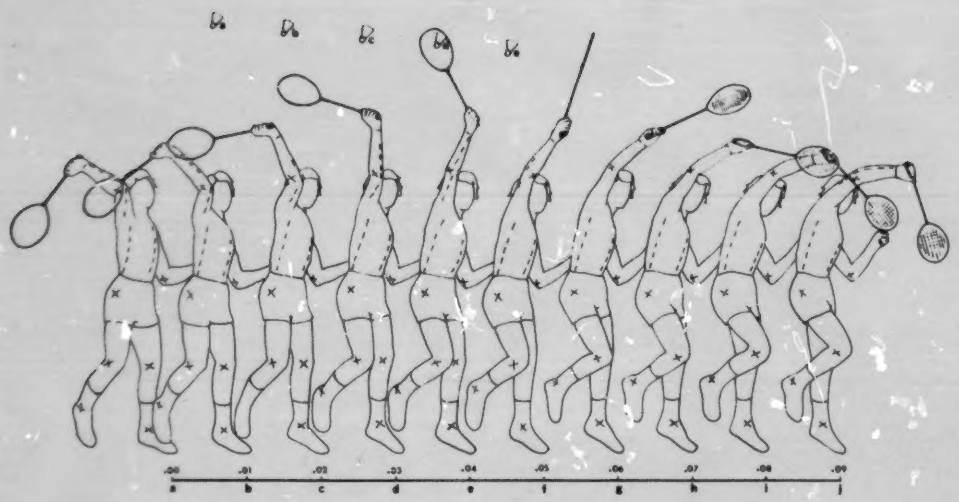


Figure 1. "Side View" of Forehand Smash.

Each of the ten tracings was hand-drawn from data on 16 mm film. Every fourth frame was selected for illustration from film moving at a transport speed of 400 frames per second; thus, the time period from one frame to the next was equal to .01 second. Contact of the racquet with the shuttlecock occurred at (f) or .05 second after the "end" of the backswing. (It should be noted that the shuttle is not illustrated at contact because the racquet obscured most of its shape as they collided.) Strips of black tape placed along the length of the "hitting" arm and at all joint "centers" reveal the turning of the arm described in the results section. See the text for an explanation of the movements depicted. The "impact side" of the racquet face is depicted by cross-hatch lines. Illustration by Sally Gadd.

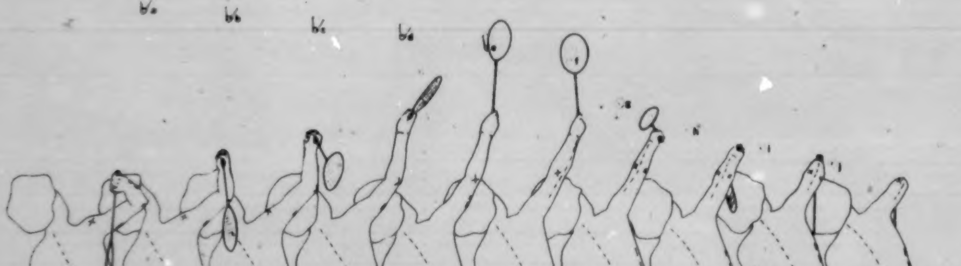
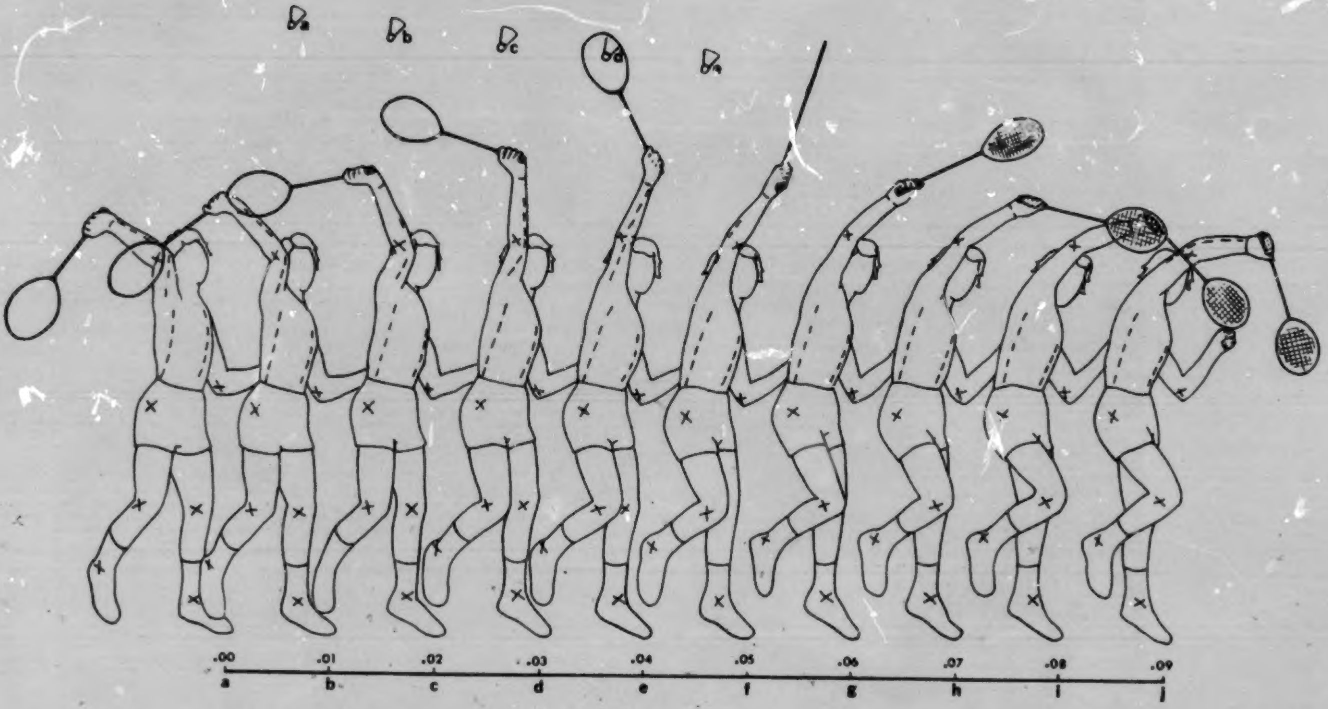


Figure 2. "Back View" of Forehand Smash.

Concomitant tracings of the data were drawn from the "back view" so that the configuration and movement of the body and racquet, at the same instant in time, could be seen. Illustration by Sally Gadd.



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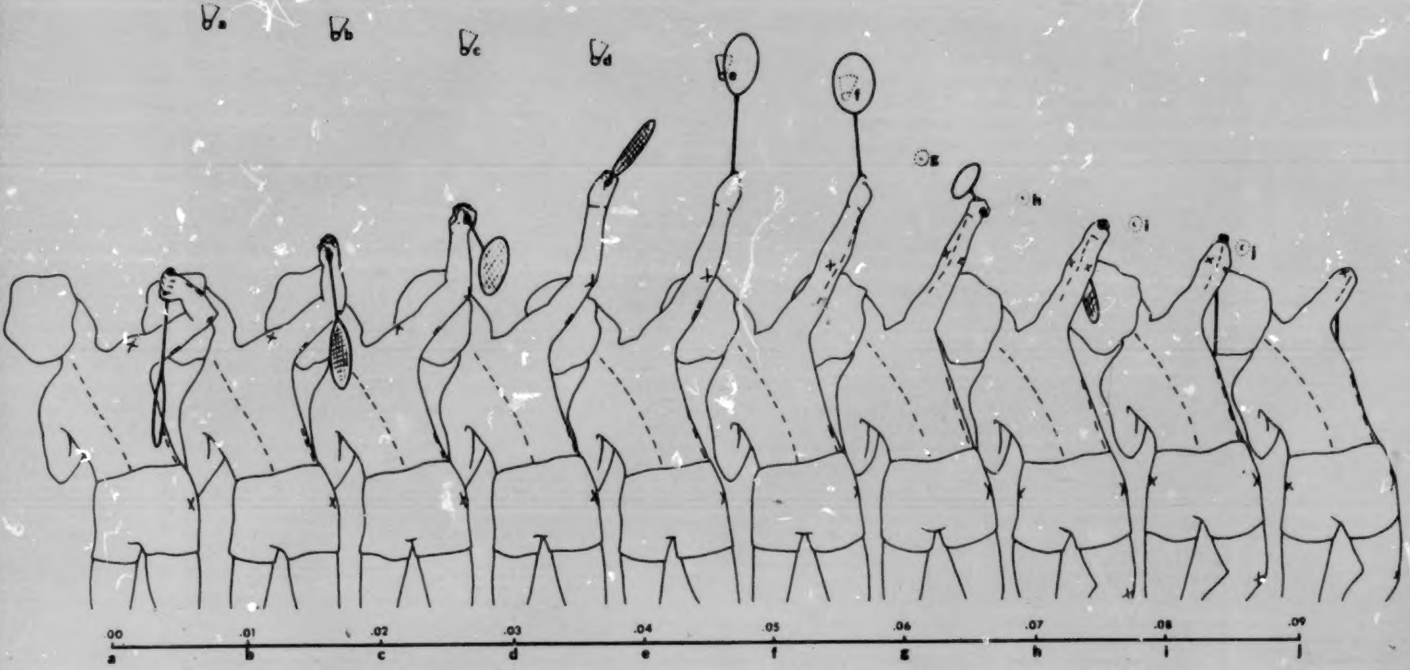
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Figure 2. "Back View" of Forehand Smash.

Concomitant tracings of the data were drawn from the "back view" so that the configuration and movement of the body and racquet, at the same instant in time, could be seen. Illustration by Sally Gadd.

> To provide the reader with some appreciation of the time elements involved, the following statements of time were taken from the forehand smash of...one of the subjects, whose smash was the most powerful of the eight players (originally studied). At approximately .05 second before contact, the upper extremity started its 'forward' movement with elbow extension (Figures 1 and 2(a)). Approximately .02 second before contact, shoulder medial rotation and forearm pronation started (Figures 1 and 2(d)). Spinal rotation and elbow extension ceased approximately .01 second before contact and elbow flexion started (Figures 1 and 2(e)). Shoulder medial rotation and radio-ulnar pronation continued through contact (Figures 1 and 2(f)), the pronation moving through the greater range of the two movements. Elbow flexion continued through contact and did not stop until at least .04 second after contact (Figures 1 and 2(j)). Throughout the action, and especially from about .08 second before contact until .04 second after contact, the wrist was held in a position of dorsi-flexion and radial flexion, and little movement was observed. Some players straightened the wrist from it's dorsiflexed position and aligned the hand with the forearm by ulnar flexion just prior to contact (Figure 2(e)); immediately after contact, the wrist returned to it's radially flexed position.

Follow-Through Phase:

> After contact, the racquet head proceeded forward and downward until it was positioned directly under the hand with the shaft vertical. At this point, the face of the racquet was perpendicular to the floor; i.e., 'on edge' when viewed from the front with the 'striking' surface of the racquet showing fully to the side view of the camera (Figure 1(j)). The racquet reached this position following contact with the shuttle by continuing elbow flexion, maximal pronation of the forearm and radial flexion of the wrist. Later, the racquet head continued it's 'general' direction down and across the body resulting mostly from spinal rotation and shoulder adduction. It is this latter position that has been stressed in the literature, probably because the positioning of the racquet is the very end of a very rapid sequence and occurs slowly enough to be perceived by the naked eye.

All players analyzed in the Commonwealth Games film used the same joint movements and sequences as described. Differences were noted in the movements of the lower extremities, the court position of the striker in relation to shuttle position, the arrangement of the feet preparatory to striking the shuttle, the range of movement of body parts, and the speed of the movements as the sequential joint actions were fluidly merged.

Lower Extremity Movement

Players used varying degrees of lower extremity flexion throughout the stroke. One pattern was consistently observed for all players: the hip and occasionally the knee of the ipsilateral leg flexed throughout the movement (Figure 1). In most cases, the ipsilateral knee was kept straighter than the illustration reveals, so that the player adopted a "forward split" position while in the air. Some players also ventriflexed at the hip joints (Figure 1 (f through j)) and at the intervertebral joints while others leaned forward from the ankles prior to and after the shuttle was struck.

The players were "air-borne" at the moment of the racquet's impact with the shuttle. The height attained during the smash varied with the player and, to some extent, with the placement of the player relative to the shuttle, but no foot contact with the floor was evident. Those players who markedly jumped for all smashes included the Malaysians, Moo, Ong and Saw. Four players, Clarkson, Czich, Jolly and Ng, played some forehand smashes with minimal elevation and jumped to maximum height for others. In these "jump" smashes, the "forward split" position was particularly pronounced.

Court Position

If a player was forced towards the back of the court and chose to hit a forehand smash, the "forward split" of the legs was used to it's maximum, first, to "balance" the body while air-borne and second, to facilitate the movement forward needed to regain mid-court position. Examples of the "forward split" while being pressed to the back of the court were seen in the performances of Clarkson, Fabris, Stevens, Webster and Youngberg. A player forced to his back-hand side usually played a "round-the-head" smash. In this instance, a considerable amount of lateral flexion of the trunk was evident though the joint mechanics of the "hitting" arm remained unchanged. The "split" of the legs changed to a "side-split" position facilitating a step sideward onto the ipsilateral leg following contact with the shuttle and a quicker return to the "ready" position. Examples of the "side-split" position were prevalent in the men's doubles and especially in the performances of Carter, Gilliland, Jolly, Moo, Ong, Priestman, Talbot and Tredgett.

Foot Arrangement

Each player executed a forehand smash with the body in a well balanced position over it's base of support with the feet positioned relatively close together, in a forward stride, and with the ipsilateral leg behind and to the side of the contralateral leg (Figures 1 and 2). On take-off, players either drove upward from both feet simultaneously or from the ipsilateral foot. Since it is the ipsilateral leg which is elevated into the "split" position previously described, the contralateral foot reached the floor first after contact with the shuttle. When a player was forced to take a smash while moving backward, the pattern of footwork did not vary; that is, take-off was from the ipsilateral foot and the contralateral foot was the landing foot. However, the most varied movement pattern was the extreme forward stride position of the feet prior to take-off and the marked "forward split" position of the legs while air-borne.

A player, who smashed while moving to the "non-hitting" side, was better positioned to hit a powerful smash because the "normal" take-off foot was on the ipsilateral side and was in a position for sideward projection at take-off. On the other hand, a player who smashed the shuttle while moving to the "hitting" side was required to compromise foot arrangement in order to use the ipsilateral foot for take-off. Most players accomplished this move by a small jump sideways to the "hitting" side placing the feet in a sideward stride position, in preparation for take-off.

Range of Speed of Joint Movement

The interdependence of range and speed of movement has been noted in a study of rapid limb movement undertaken by one of the authors (2). The cause-effect relationship of these two variables necessitated that they be discussed together. Range and speed of joint movement was specific to the player. For example, Czich and Stevens tended to use large ranges and slower speeds of movement during the backswing, hence a longer time to reach the "end" of the backswing; this, in turn, necessitated a follow-through commensurately large in range (and long in time) to accommodate the deceleration phase of racquet and body parts. The player thus had less time to prepare for the next stroke. On the other hand, Talbot, Ganguli and, in particular, Prakash employed smaller ranges and faster speeds of backswing actions, completed the follow-through more quickly and were able to be properly prepared for any return of the smash.

The performance of Prakash was particularly exemplary of the interplay of range and speed. He moved no more than two steps in any direction on court, played powerful smashes with little apparent effort and achieved both speed and accuracy of the shuttle. He employed small ranges of movement and speeds of backswing actions which were remarkably fast. The authors conjuncture that Prakash attained a speed of backswing which provided an optimal load effect on his muscles; not so fast that the "inertial load effect" would dissipate muscle force, but sufficiently fast to capitalize on the maximum acceleration produced at the reversal of the movement. The milliseconds of time he saved with efficient stroking were sufficient for him to regain his "ready" position in preparation for any return. While all players moved quickly and initiated the backswing rapidly, Prakash capitalized on speed more than any other. In past studies, the biomechanical and physiological advantages of a "fast" backswing have been explained (3) and described (5,13).

His footwork was equally intriguing! In most cases, his body weight was "balanced" over his small base of support, with his contralateral foot slightly in front. His elevation for a smash varied, but in most cases, he did not jump. Instead, he took off from his ipsilateral foot and, in quick succession following impact, took his weight onto his contralateral foot as his ipsilateral leg was raised only slightly to "counter" the forward rotation of his upper body.

Prakash won the Commonwealth Games Men's Singles Title. Apart from strategy, his success was due in no small part to his accurate and efficient stroke production. The efficiency is attributed to his optimal ranges of movement coupled with precise timing within a series of purposeful joint actions.

Some players who struck the shuttle with marked force made use of two-joint movements only partially utilized by others. They initiated the "forward" action with a strong spinal rotation and dorsiflexion of the vertebrae. The range of these two movements was sufficiently large that the left upper extremity (for right-handed players) appeared to lead the action by reaching toward the left, away from the body. The rotation, which was timed so that it was still operative about .01 second before contact (Figures 1 and 2 (e)), was apparently facilitated by a marked "arch" of the upper body. These movements were particularly evident in Czich, Moo, Ong, Prakash, Stevens and Talbot.

Summary

When hitting a forehand smash, each of the international elite players employed the same series of joint movements that were previously described for nationally-ranked Canadians. Some differences in lower extremity movement were noted. Differences were described when court position of the hitter or foot arrangement of the player was seen to require a deviation from the so-called "desirable" position and arrangement. Some players used joint movements over a wider range than others, and some specifically limited the range, facilitating very rapid movements. Two variables range and speed, could not be considered in isolation. All players took the racquet back quickly, and without hesitation at the "end" of the backswing, brought the racquet through forcefully. However, the range, hence the speed of backswing motion, varied considerably. A reasonable conclusion is that a "limited" range of backswing, sufficient to allow all of the heretofore-mentioned joint movements to occur, resulted in a more effective smash.

It should be noted that the Canadians, Czich and Priestman, filmed under laboratory conditions in previous studies, employed the same motor patterns when filmed on court under competitive conditions.

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COMPARISON OF SELECTED FACTORS ASSOCIATED WITH THE FLAT AND SLICE SERVES OF MALE VARSITY TENNIS PLAYERS

by

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Abstract

The main purpose of this study was to describe and compare selected kinematic and kinetic parameters associated with the flat and slice tennis serves as executed by male intercollegaiate tennis players. Kinetic factors included ball and racquet velocities, angle of ball projection, position of racquet face at racquet/ball contact, location of total body center of gravity, and timing of the weight shift changes. Temporal periods for various aspects of the service action were also determined. The kinetic analysis was concerned with the vertical ground reaction force and impulse values were determined. A secondary purpose was to study the relationship between total body center of gravity and selected spatial positions of the ball during the tossing component of the service.

Five male tennis players with intercollegiate playing experience were filmed at 250fps with a LOCAM camera using black and white film (Kodak 2498). Each subject served while standing on a four-foot square force platform. A minimum of 2 trials of each type of serve was recorded. Additional trials were required of those subjects who failed to execute a legal serve to the right service court within the minimum number allotted. Serve placement was recorded and was the basis for selection of the 5 flat and 5 slice serves for analysis purposes. Those serves landing in the service court closest to the service line were selected for the analysis. Film and force recording data were matched on a time basis to the nearest .01 second.

Comparison of mean values for all measures between flat and slice serves warranted the following conclusion: The largest differences between the two types of serves were observed in terms of ball velocity and racquet face position at contact. Additionally, it was concluded that a definite sequence of specific movements was followed during the execution of the service motion.

Despite the wide popularity of the game of tennis, few scientific studies have been reported in which the researchers have focused their investigations on the individual skills of this racquet sport. Quantitative studies dealing with the tennis serve are particularly limited in number. As a result, much of the information that is known about the tennis serve has come from the published opinions, beliefs, and observations of tennis coaches, teachers and players. Therefore, a biomechanical study of high level performance tennis players was considered necessary.

The main purpose of this research was to determine and compare selected kinematic parameters associated with the flat and slice tennis serves as executed by male varsity tennis players. The kinematic analysis involved the determination of such factors as racquet velocity during the forward swing phase and at the racquet/ball contact point, resultant ball velocity, angle of ball projection off the racquet, and center of gravity location and displacement.

A temporal analysis of various aspects of the service motion was also conducted. This analysis was concerned with the following designated phases: 1) backswing phase; 2) forward swing phase; 3) weight shift changes; 4) duration from the starting position to ball release; 5) duration from ball release to the highest position in the toss, 6) duration from the highest position in the toss to contact; and 7) duration from ball release to contact.

A second purpose of this study was to determine the relationship between the total body center of gravity and selected positions of the ball during the tossing component of the service action. The positions included those of the ball at the time of release, the highest point in the toss, and racquet/ball contact.

Five male tennis players were the subjects in this study. Four players were currently competing at the inter-collegiate level and the fifth subject was a former varsity competitor who presently coaches at the collegiate level. Complete descriptive data for each subject including racquet preference and specifications is included in Table 1.

The subjects were filmed at 250 frames per second with a LOCAM camera using black and white film (Kodak 2498). A minimum of two trials of each type of serve was recorded. Additional trials were required of those subjects who failed to execute a legal serve to the right service court within the minimum number allotted. Service placement was recorded and was the basis for selection of the five flat and five slice serves for analysis purposes. Those serves landing in the service court closest to the service line were selected for the analysis.

Mean values were computed for all variables and served as the basis for the comparison of the flat and slice serves. For the present discussion, attention will be focused on the following two aspects of the study: 1) the temporal analysis and, 2) location of total body center of gravity (COG) at designated times during the service motion.

The temporal analysis included a study of various, distinct sequences that could be isolated within the total service motion. These sequences were identified either in terms of specified phases during the serve or in relation to various positions of the ball during the tossing motion.

The backswing phase was initiated with the backward and downward movement of the racquet and was completed when the racquet head descended to it's lowest position behind the server's back. The forward swing phase consisted of the forward and upward movement of the racquet head from the lowest position behind the server's back until racquet/ball contact.

Mean values for the designated sequences of the service motion revealed a consistent temporal pattern between flat and slice serves. These values are reported in Table 2.

TABLE 1

AGE, PHYSICAL CHARACTERISTICS, AND RACQUET SPECIFICATION OF THE SUBJECTS

Subject Number	Age (yr)	Height (in)	Weight (lb)	Racquet Brand and Model		Racquet Weight (oz)	String type	String tension (lb)
1	20	75	185	Garcia Gragin 240 Pro	4 5/8	14.2	Gut	62
2	20	70	145	Wilson Jack Kramer	4 1/2	14.0	Gut	57
3	28	72	175	Spaulding Intimidator	4 1/2	13.5	Gut	55
4	20	72	178	Head Master	4 5/8	14.5	Gut	58
5	19	72	160	Yonex 7500	4 5/8	14.5	Gut	59
Mean	21.40	72.20	168.60			14.14		58.20
S.D.	3.71	1.78	16.04			.42		2.59
Maximum	28	75	185			14.50		62
Minimum	19	70	145			13.50		55
Range	8	5	40			1.00		7

TABLE 2

SUMMARY OF TEMPORAL DATA MEASURED IN SECONDS FOR VARIOUS PHASES OF THE FLAT AND SLICE TENNIS SERVES

Temporal Phase	Flat Serve	Slice Serve
Backswing	1.6260	1.5997
Forward Swing	.1322	.1334
Total	1.7582	1.7331
Backward Displacement of COG	.5313	.5460
Start to Ball Release	.9838	.9594
Ball Release to Contact	.7752	.7737
Release to Highest Point	.5105	.5110
Highest Point to Contact	.2647	.2627

On an individual basis, the longest backswing time was 2.0026 seconds for the flat serve and the shortest time was 1.2312 seconds. For the slice serves, the longest and shortest backswing times were 2.0710 and 1.2360 seconds, respectively.

For the forward swing phase, the longest and shortest times for the flat serves were .1482 and .1064 seconds, respectively. In comparison, the corresponding times for the slice serves were .1560 and .1200 seconds.

In terms of total time, the longest and shortest flat serves were 2.1280 and 1.3376 seconds, respectively in duration. The corresponding times for the slice serves were 2.1926 and 1.3560 seconds.

Within the total time of the execution of the service motion from the starting position to time of contact, timing of the body weight shift changes were noted by the displacement of the total body center of gravity. Displacement of the total body COG reflected a backward movement away from the baseline during the

The location of the total body center of gravity provided the basis for determining the point about which the server's weight was distributed. Total body COG was then utilized as a reference point for comparing various body positions assumed by the server during the execution of the two types of serves. The selected body positions made it possible to study the server's weight distribution relative to stance width and to the front toe of the server at racquet/ball contact.

Horizontal distance between the feet of the server was determined for each subject in the starting position for each type of service. The intersection of the line of gravity with the stance width line indicated the weight distribution of each subject relative to stance width. Horizontal distances for stance width and from the line of gravity to the front toe of the server are presented in Table 3. Since differences existed in the widths of the stance among subjects, the percentage of the distance from the location of the line of gravity between the feet of the server relative to stance width is also reported.

While mean values seemed to indicate that the distribution of weight of the server in the starting position was balanced almost evenly between both feet, individual comparisons between subjects indicated otherwise. Three of the subjects displayed a pattern of weight distribution toward the rear foot. The weight of Subject 2 was distributed toward the front foot whereas that for Subject 4 was balanced evenly between both feet. Perhaps the most pertinent fact revealed by the data was the consistency of the weight distribution pattern evidenced for each subject regardless of the type of serve being executed.

The determination of the line of gravity relative to stance width when total body COG was at its maximum backward position was also made. This information is presented in Table 4. The mean horizontal distances from the line of gravity

TABLE 3

MEASURES EXPRESSED IN FEET OF STANCE WIDTH AND HORIZONTAL DISTANCE FROM THE LINE OF GRAVITY TO THE FRONT TOE OF THE SERVER IN THE STARTING POSITION FOR THE FLAT AND SLICE TENNIS SERVES

Subject Number	FLAT SERVE			SLICE SERVE		
	Stance Width	Gravity line distance to front toe	% of distance from gravity line behind front toe to stance width	Stance Width	Gravity line distance to front toe	% of distance from gravity line behind front toe to stance width
1	1.62	1.21	74.69	1.78	1.10	61.80
2	2.09	.79	37.80	1.94	.72	37.11
3	1.88	1.31	69.68	1.61	1.08	67.08
4	2.14	1.02	47.67	2.11	.96	45.50
5	1.66	1.20	72.29	1.64	1.00	60.98
Mean	1.88	1.11	60.42	1.82	.97	54.50
S. D.	.21	.18	14.86	.19	.14	11.29
Maximum	2.14	1.31	74.69	2.11	1.10	67.08
Minimum	1.62	.79	37.80	1.61	.72	37.11
Range	.52	.52	36.89	.50	.38	29.97

TABLE 4

MEASURES EXPRESSED IN FEET OF STANCE WIDTH AND HORIZONTAL DISTANCE FROM THE LINE OF GRAVITY TO THE FRONT TOE OF THE SERVER AT THE TIME OF MAXIMUM BACKWARD POSITION OF THE COG FOR THE FLAT AND SLICE TENNIS SERVES

Subject Number	FLAT SERVE			SLICE SERVE		
	Stance Width	Gravity line distance to front toe	% of distance from gravity line behind front toe to stance width	Stance Width	Gravity line distance to front toe	% of distance from gravity line behind front toe to stance width
1	1.60	1.31	81.86	1.71	1.21	70.76
2	2.09	1.29	61.72	2.00	1.29	64.50
3	1.86	1.47	79.03	1.67	1.21	72.46
4	2.09	1.39	66.51	2.04	1.36	66.67
5	1.60	1.35	84.38	1.67	1.33	79.64
Mean	1.85	1.36	74.70	1.82	1.28	70.81
S.D.	.22	.06	8.94	.17	.06	5.25
Maximum	2.09	1.47	84.38	2.04	1.36	79.64
Minimum	1.60	1.29	61.72	1.67	1.21	64.50
Range	.49	.18	21.66	.37	.15	15.14

to the front toe relative to stance width also showed similarities between the two types of serves. Expressed as a percentage of the stance width, the mean value for the distance from the line of gravity between the feet of the server was 74.70% for the flat serves. This compared with the corresponding value of 70.81% for the slice serves. More agreement was thus noted in terms of weight distribution relative to stance width at maximum backward position of the COG than at the starting position of the service action.

Despite the concensus expressed in the literature that a player's weight would be primarily on the rear foot at some point during the service motion, the results from this study did not support his claim. In proportion to stance width, the position of the line of gravity was displaced farthest in the backward direction for Subject 5 during the execution of the flat serve. Since this position was three inches in front of the rear foot, the server's weight should not be considered to rest primarily on the rear foot at any point during the serving motion.

Neither did the analysis of the data in this study support the contention that a player's weight is on the front foot at the time of racquet/ball contact. The horizontal distances from the line of gravity at racquet/ball contact are presented in Table 5 for both the flat and slice serves. The line of gravity fell in front of the forward foot for all sequences that were analyzed.

TABLE 5

HORIZONTAL DISTANCES MEASURED IN FEET FROM THE LINE OF GRAVITY TO THE FRONT TOE OF THE SERVER AT TIME OF RACQUET/BALL CONTACT FOR THE FLAT AND SLICE SERVES

Subject Number	Flat Serve	Slice Serve	Difference
1	.45	.70	.25
2	.45	1.28	.83
3	.72	1.06	.34
4	1.04	1.75	.71
5	1.45	2.13	.68
Mean	.82	1.36	.56
Standard Deviation	.38	.48	.23

Mean horizontal distance from total body COG to the front toe of the server was .82 feet for the flat serve and 1.36 feet for the slice serve. In comparing the two types of serves, differences between the distance from the line of gravity to the front toe were observed for all subjects. The mean value of these differences represented a distance of approximately 6.75 inches and was considered to represent a real difference in the position of body weight between the two types of serves.

The findings of this study, with regard to the temporal analysis and the location and displacement of the total body center of gravity, appeared to substantiate the following conclusions:

1) There was a consistent temporal pattern between the flat and slice serves for each subject.
2) Differences between the two types of serves were observed in terms of the distance between the line of gravity and the front toe of the server at the time of racquet/ball contact.

CHARACTERISTICS OF THE BADMINTON SMASH STROKE

by

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Abstract

A Lo-Cam camera operating at 150 or 200 frames per second was used to film sixty smashes of twenty-two finalists participating in the 1978 Commonwealth Games in Edmonton, Canada. The smashes of 14 males and 8 females were analyzed to determine velocity of shuttle flight prior to and post-contact, height of jump as determined by estimated centers of gravity of body, and timing sequence of the smash began with (1) a take-off from one foot and rise of the whole body center of gravity until, (2) a high point was reached with racquet in the "cocked position", this was followed by (3) rotation of the hips in the transverse plane while the whole body center of gravity lowered slightly, (4) then contact with the shuttle occurred, ending with (5) touchdown with the opposite foot. The pre-flight velocities were similar between sexes and events, whereas, the pre-flight angle was 20^{o} greater in the singles game than in the doubles game. The total average shuttle velocity post-contact was 58.56 meters/second (130.94 miles/hour) at 7^{o} below the horizontal. Female average post-contact shuttle velocity was 97.5% that of males (59.28 meters/second, 132.55 miles/hour) in all events. Males directed the smashed shuttle downward (7.1^{o}) more than females (5.1^{o}). Males jumped an average of 20.1 centimeters, whereas the females jumped an average of 9.2 centimeters. The Asiatic athletes (Malaysia and India) jumped an average of 2.3 centimeters higher (16.9 centimeters) than the other athletes (England, New Zealand, Australia, Scotland, Canada) (14.6 centimeters).

In the sport of badminton, the smash stroke is the power stroke used to gain a point advantage by projecting the shuttlecock downward across the net and aimed at the opponent's side backcourt area.

Poole states (2) that "the angle is more important than the speed of the smash, so the shuttle should be contacted from as high as possible. The racquet face is pointed downward at the contact point and the shuttle is hit in front of the body. The forearm and wrist rotation is very fast and forceful so that the shuttle travels at a rapid downward trajectory". (p. 26-27). He also points out (p. 22) that the smash will differ from other two overhead strokes in terms of: 1) contact point. 2) speed of rotation, and 3) angle of the shuttle leaves the racquet.

Investigators have analyzed the smash stroke; however, most have compared it to other badminton or overhand patterns. Adrian and Enberg (1) filmed a highly-skilled player and determined that the subject stepped forward while executing a badminton smash, but did not jump. They also found the overhead smash timing sequence to begin with the establishment of the base of support followed by pelvic rotation and a classic unwinding sequence for force production. The shuttlecock velocity post-contact for the woman subject was reported at 55.96 m/s (183.7 f/s).

Tsukahara (3) filmed badminton strokes of eight highly-skilled players from Japan. He found that the shuttlecock 53.7 m/s for the smash. This was the fastest of all strokes.

Describing the smash as it is used by badminton players in international competition is the purpose of this paper.

METHODOLOGY

A Lo-Cam camera operating at 150 or 200 frames per second was used to film 57 smashes of 21 finalists (13 men and 8 women) participating in the 1978 Commonwealth Games in Edmonton, Canada. The camera film rate was determined by marks placed on the film via a pulse generator operating at 100 cps. A zoom lens was used to obtain the side view of the smash from a distance of approximately 18 meters.

Mean height and weight data for the eight women and thirteen men subjects (excluding the 2 Scottish subjects for whom these data were not available) appear in Table 1. Of the subjects' smashes, 19 subjects were filmed during semi-final or final competition.

TABLE 1

MEAN HEIGHT AND WEIGHT OF BADMINTON PLAYERS

Means	n	Weight		Height	
		(pounds)	(Newtons)	(in.)	(cm.)
Men	12	150.5	68.4	68.8	174.0
		(17.15)[a]	(7.86)	(2.49)	(6.21)
Malaysia	5	134.4	61.0	66.6	168.6
		(12.28)	(5.61)	(2.07)	(5.41)
Australia, Canada, England, India, New Zealand	7	162.0	73.6	70.3	177.9
		(8.27)	(3.74)	(1.38)	(3.08)
Women	7	136.4	62.0	67.3	170.7
		(5.35)	(2.44)	(1.50)	(3.45)

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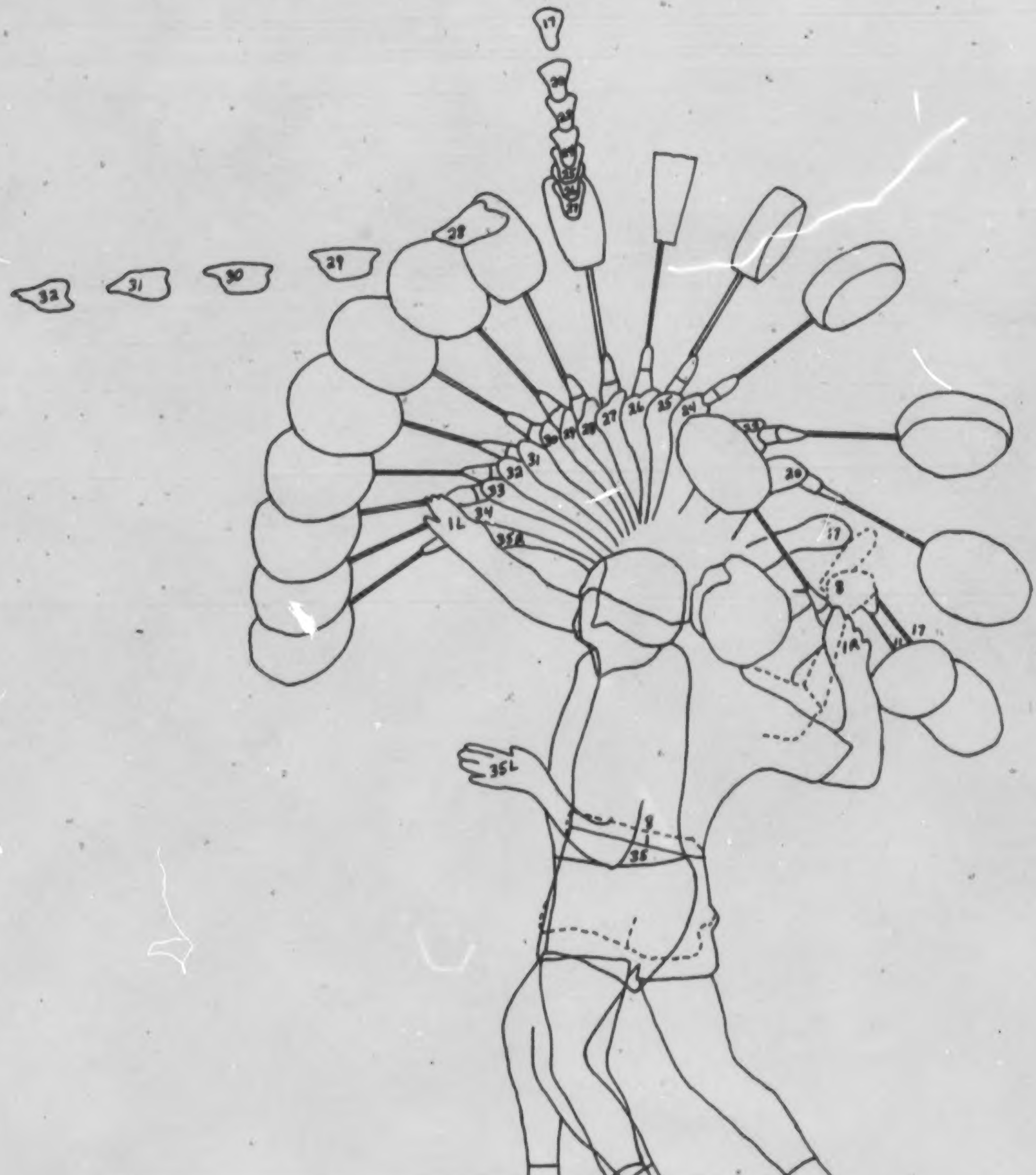
[a] ( ) = standard deviations

RESULTS

A contourogram of a typical badminton smash is depicted in Figure 1.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35L
35
9
35R
1L
35L
1R

Figure I. Contourogram of a Badminton Smash Stroke Representative of Players at the 1978 British Commonwealth Games

Duration of the Phases of the Badminton Smash

The duration of the phases from takeoff to touchdown for all events is shown in Figure 2. Generally, the timing sequence of the badminton smash was as follows: 1) a takeoff from one foot and rise of the whole body center of gravity until, 2) a high point was reached with racquet in the "cocked position" ($\bar{X}$ = 0.117 sec), this was followed by 3) rotation of the hips in the transverse plane while the whole body center of gravity lowered slightly, 4) then contact with the shuttlecock occurred, ending with 5) touchdown with the opposite foot. The mean times for each phase of the stroke were different between the doubles and singles events and between the two sexes, except the phase from high point to contact. There is a shorter air time for singles events ($\bar{X}$ = 0.204 sec) as compared with 0.318 sec ($\bar{X}$) for doubles events.

Velocity of Shuttlecock

The velocities of shuttlecock flight prior to and post contact were determined by the equation

$$V = \frac{\Delta d}{\Delta t}$$

where V = velocity

Δd = change in distance

Δt = change in time

Time increments from 0.0132 seconds (2 frames) to 0.0329 seconds (5 frames) post contact were used. The scale conversion was determined from the racquet head span which was 24.7 centimeters. The angle of shuttlecock flight is expressed with respect to the horizontal as reflected in Figure 3.

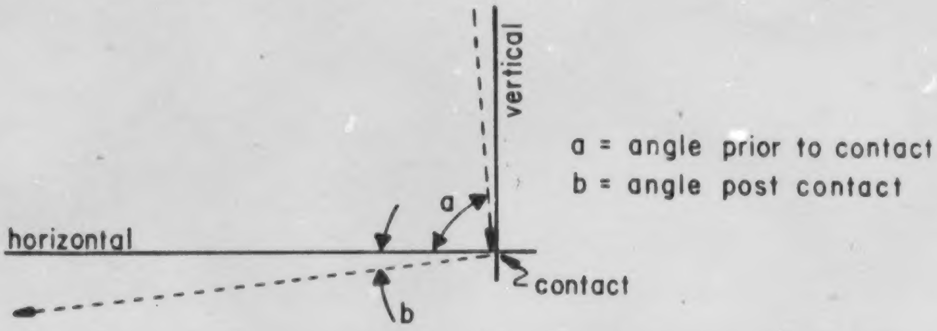

Figure 3. Angle of Shuttlecock Flight

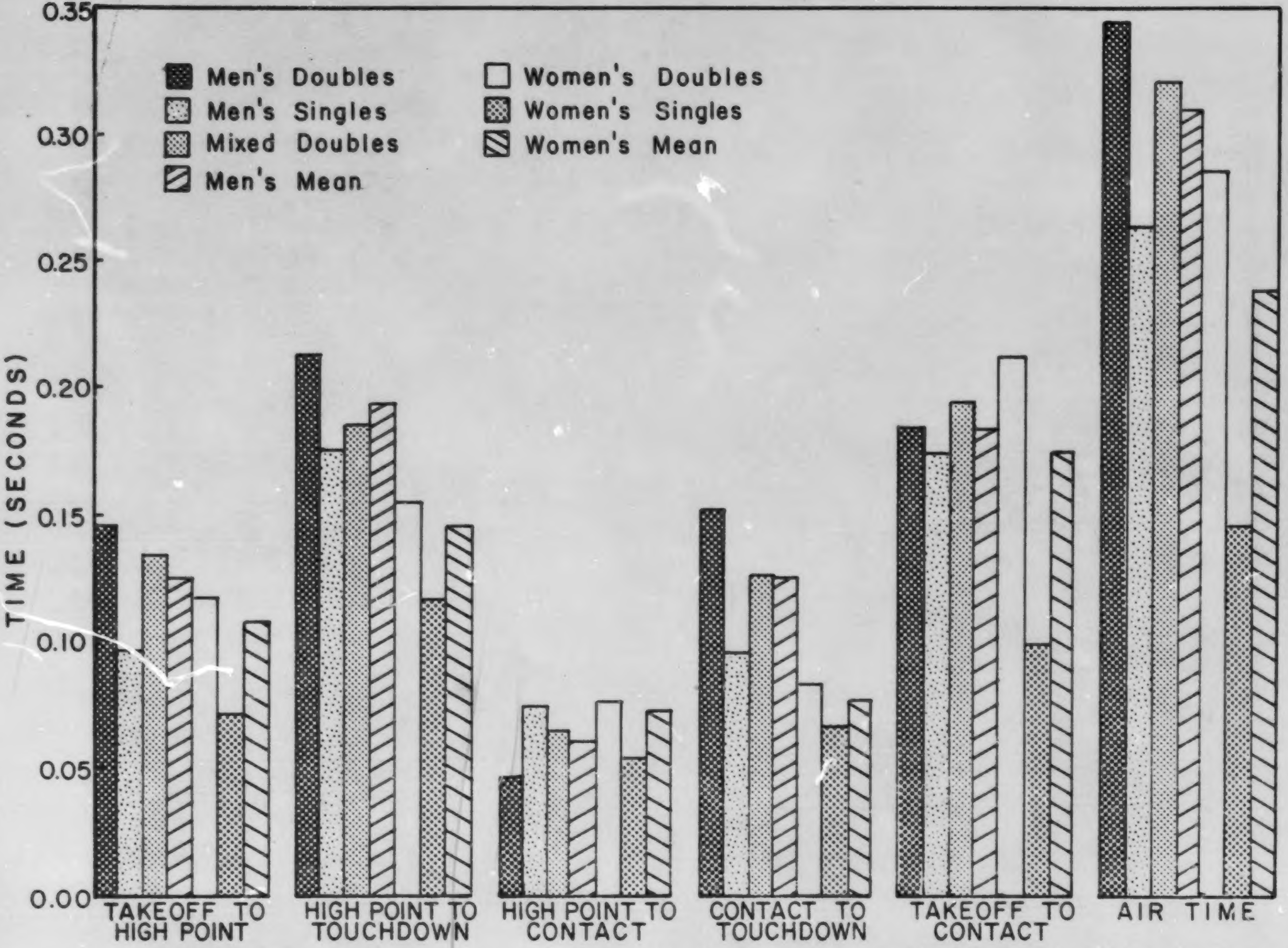

Figure 2. Duration of Phases of Badminton Smash Strokes Occurring in the 1978 British Commonwealth Games

The histogram of Figure 4 shows the mean speed of shuttlecock flight prior to contact, and that of Figure 5 shows the mean angle of shuttlecock flight with respect to the horizontal. Similarly, the histogram of Figure 6 shows the mean speed of shuttlecock flight post contact, and that of Figure 7 shows the mean angle of shuttlecock flight with respect to the horizontal post contact.

The prior to contact shuttlecock velocities were similar values among the athletes in all events. The total average shuttlecock velocity post contact was 58.56 m/s (130.94 m/h) at 6.2^0 below the horizontal. The men mixed doubles shuttlecock velocity was slower than the other events ($\bar{X} = 44.61$ m/s). For the women the average post contact shuttlecock speed was 97.5% that of the men (59.28 m/s, 132.55m/h).

In comparing the angle of shuttlecock flight in the singles game to the doubles game prior to contact, the angle in the singles game is much greater ($\bar{X} = 55.5^0$). However, the post-contact angle of shuttlecock flight in the singles game is slightly less ($\bar{X} = 6.1^0$) than in the doubles game ($\bar{X} = 7.3^0$). Men directed the smashed shuttlecock downward more than did women (7.5^0 as compared with 5.0^0).

The men from Malaysia post contact mean shuttlecock speed was 67.20 m/s; whereas, the other men showed a mean shuttlecock speed of 54.39 m/s. The post contact mean angles were similar between the two groups representing different ethnic backgrounds.

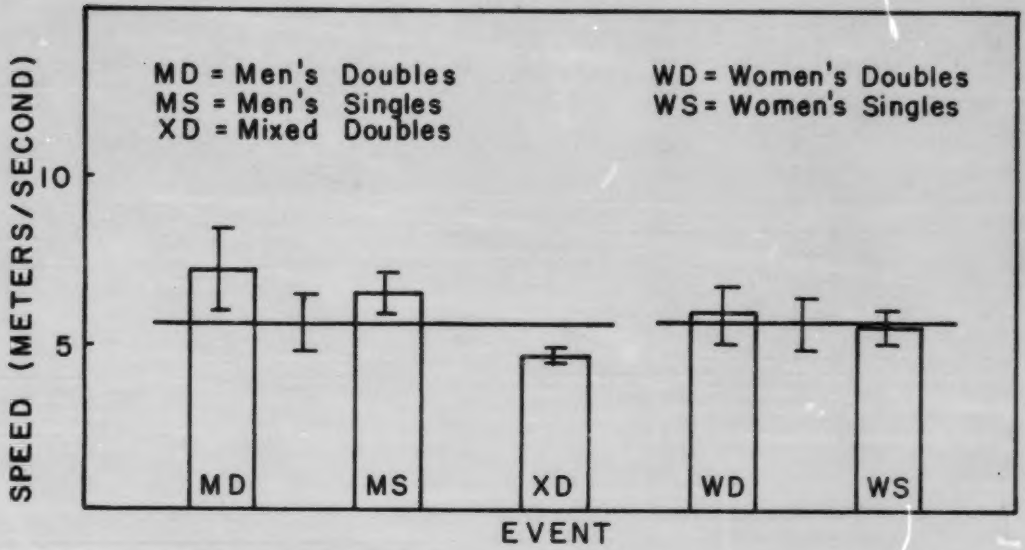

Figure 4. Mean Speed of Shuttlecock Flight Before Execution of Badminton Smash

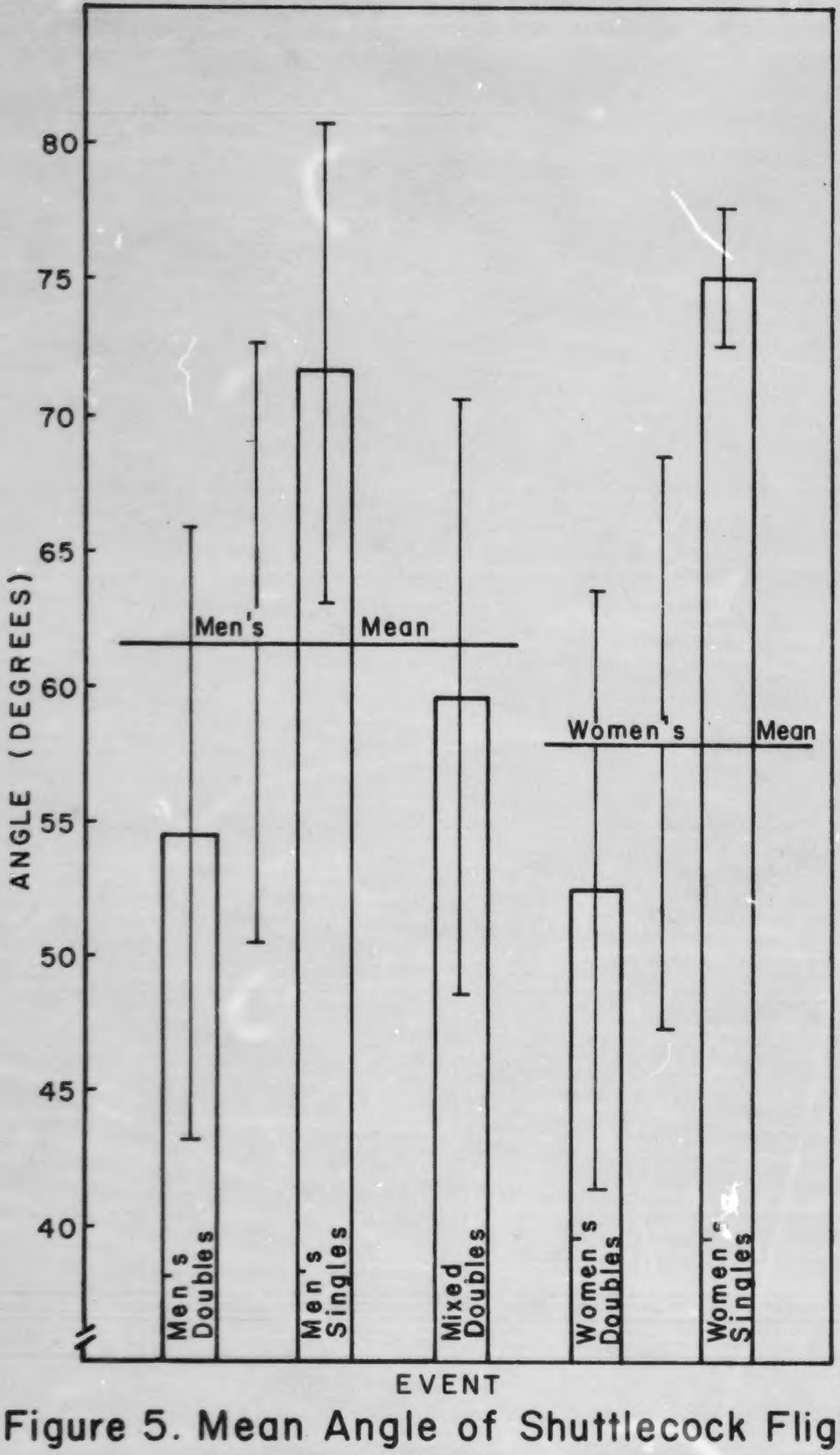

Figure 5. Mean Angle of Shuttlecock Flight With Respect to the Horizontal Before Execution of Badminton Smash

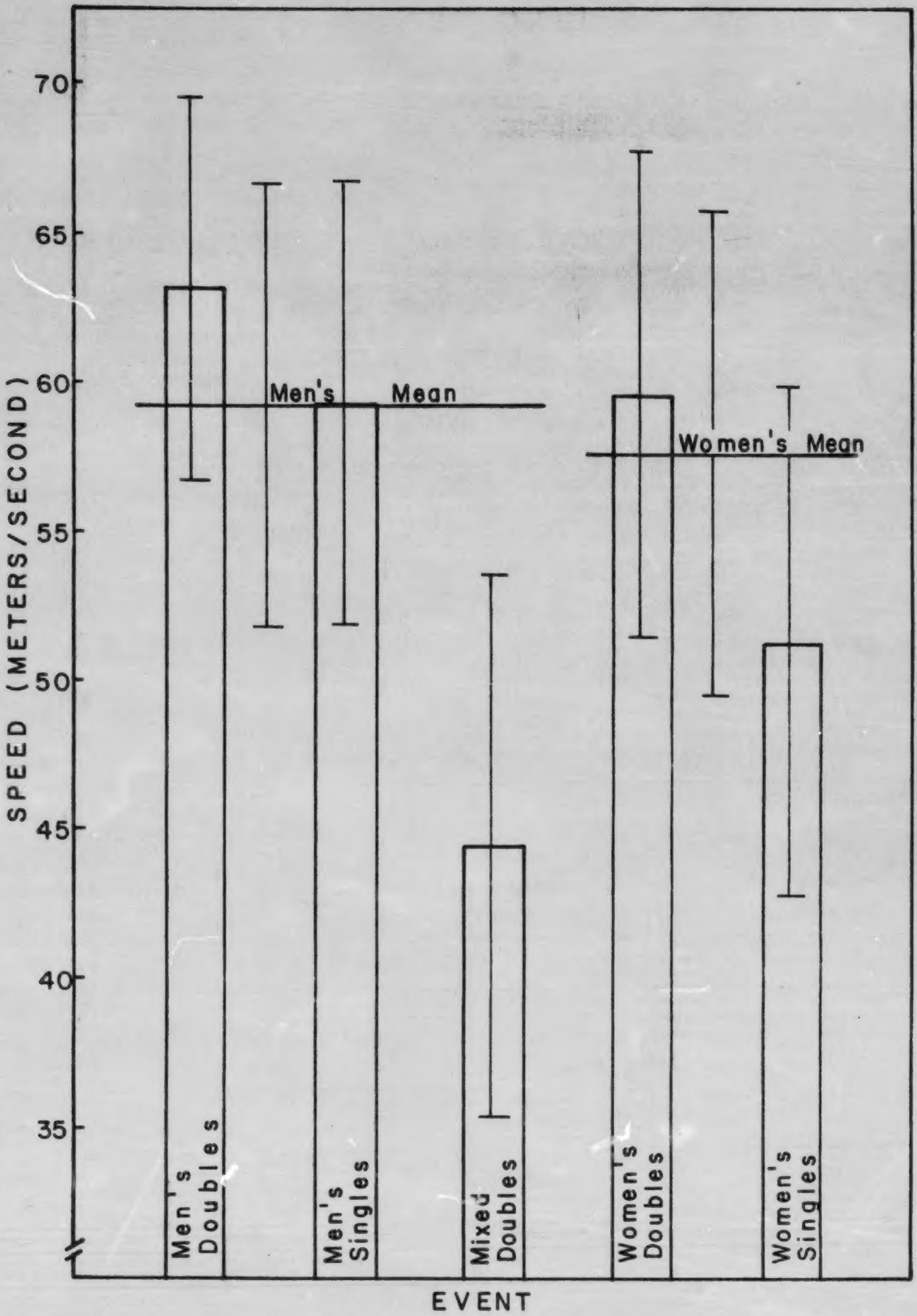

Figure 6. Mean Speed of Shuttlecock Flight After Execution of Badminton Smash

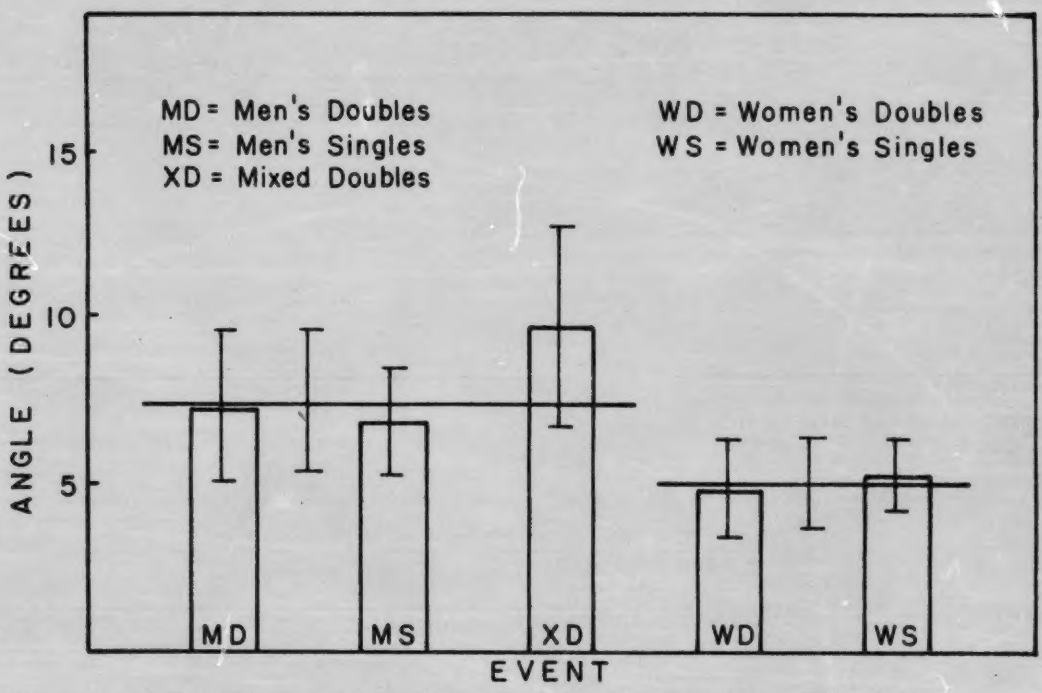

Figure 7. Mean Angle of Shuttlecock Flight With Respect to the Horizontal After Execution of Badminton Smash

Height of Jump

The height of jump was determined by estimating the center of gravity to be at the subjects' waist and subsequently measuring the change in distance of this point between takeoff and high point (up) and between high point and touchdown (down). Figure 8 shows a discrepancy between these two values. This discrepancy may be attributed to 1) perspective error where the subjects did not always move perpendicular to the camera lens; 2) court position of the subject, and 3) the trunk rotation and flexion of body parts which showed the estimated center of gravity to be unusually lower on landing than on takeoff. The mean of the two values (up and down) was used to construct the histogram, Figure 8.

Men jumped an average of 17.3 centimeters, whereas the women jumped an average of 13.7 centimeters during the execution of the badminton smash. The male subjects from Malaysia jumped an average of 9.6 centimeters higher (22.14 cm) than the males from Australia, Canada, England, India, New Zealand, Scotland (12.5cm). Because of the method used, the height of the jump may have been underestimated for the performance of the males from Malaysia, since they hyperextended the back and hip angle more than did the other subjects. The values of the height jumped by the Malaysians are representative of the subjects' performance and not necessarily actual values. The sample size for women was too small for comparisons to be made.

DISCUSSION

Using Poole's description of the smash stroke as a criterion for comparison, it was found that the mean post contact speeds imparted to the shuttlecock were within 1.5 m/s for men and women. However, shuttlecock speed variation is greatest for the mixed doubles event compared to all other

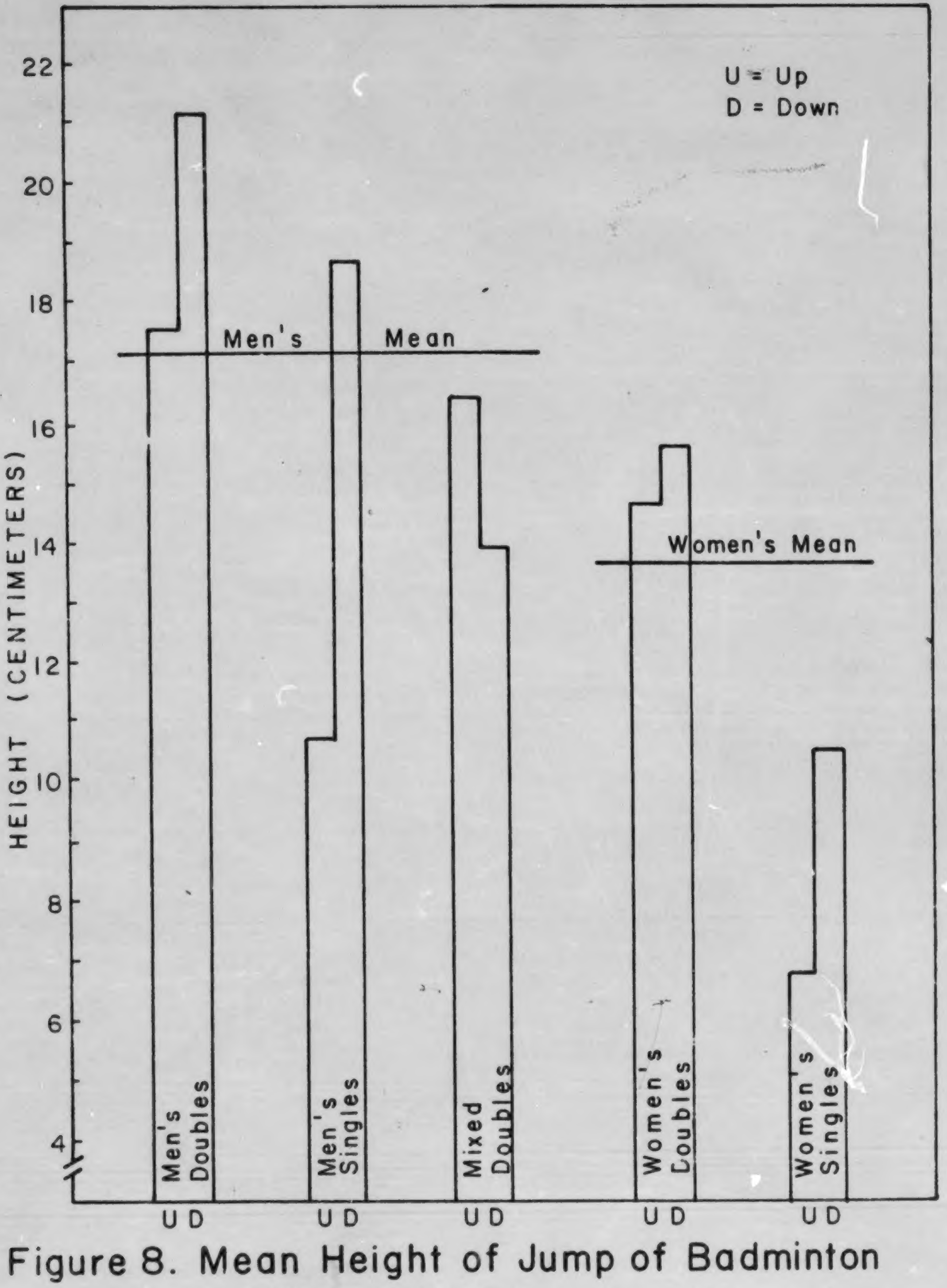

Figure 8. Mean Height of Jump of Badminton Players While Executing the Badminton Smash

events. The shuttlecock speed is also dependent upon the game situation such as court position and relative time in which to execute the smash. The mean angle of trajectory post contact was more effective for the males than females. The men in this sample were 2.5 centimeters taller ($\bar{X}$ = 174.0 cm) and jumped 5 centimeters higher ($\bar{X}$ = 17.3cm) than the women. Since the general arm and trunk mechanics of the smash did not differ between men and women, the men contacted the shuttlecock at a greater height than did the women. This explains the difference in trajectory angle between men and women when executing the badminton smash. The men in mixed doubles play directed the smashed shuttlecock downward more ($\bar{X} = 9.8^{\circ}$) than they did in the other two events.

Although Poole (2), Adrian and Enberg (1), and others do not identify the jump as an integral part of the badminton smash, the data from this sample show that the jump is an important component of the badminton smash of excellent badminton players. The observation that players from Malaysia jump higher ($\bar{X}$ =22.1cm) than the other players ($\bar{X}$ = 12.5 cm) can be attributed to the accomodation that smaller statured subjects ($\bar{X}$ = 168.6 cm) have made to contact the shuttlecock at relatively the same angle ($\bar{X} = 7.3^{\circ}$) as the taller statured ($\bar{X}$ = 177.9 cm) subjects ($\bar{X} = 6.9^{\circ}$).The speed of the shuttlecock post contact for the Malaysian players ($\bar{X}$ =67.20 m/s) is faster than that of the other male players ($\bar{X}$ = 54.39 m/s). This may be attributed to the back hyperextension and smaller radial distance through which the racquet moves. Being lighter weight (X = 61.0 N) the Malaysians also have less mass and inertia to move when executing the badminton smash than the heavier players ($\bar{X}$ = 74.5 cm).

The women players, who are smaller statured($\bar{X}$ = 171.5 cm) than the men, had a mean jump height greater than that of the men when the Malaysian players were eliminated from the male sample. The lesser angle of projection, therefore, is attributable to the lesser speed of the shuttlecock by the women, not to their lesser jumping height.

The speeds of the shuttlecock after contact are similar to the references stated. Tsukahara (3) used a slower filming rate of 60 frames per second and determined the maximum initial speed after contact of his sample to be 62.4 m/s. Translating Adrian and Enberg's angular velocity data of the arm and racquet movement (6000°/sec) into linear velocity the estimated velocity of the end of the racquet and therefore the speed of shuttlecock would be more than 80 m/sec. This is comparable to the highest speed recorded with this sample.

CONCLUSIONS

Although this sample of expert badminton players is small, the results show differences of the badminton smash with respect to events, sex, stature, and ethnic origin. The implications for badminton coaches in the smash execution are that the jump is an integral part of the stroke, and that mixed doubles play is characterized by a lesser post contact shuttlecock speed and greater angle of flight with respect to the horizontal in comparison to the other events.

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RELATIONSHIP BETWEEN BALL VELOCITY AND SELECTED BIOMECHANICAL FACTORS OF THE FOREHAND KILL IN RACQUETBALL*

by

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Abstract

The purpose of this study was to identify mechanical aspects that enhance performance of a forehand kill shot. High speed cinematographic techniques (100 frames/sec) and radar applications were used to investigate the performance of 8 'A' through 'C' level male athletes in the performance of the forehand kill in racquetball for the purpose of determining the relationship between ball velocity and selected biomechanical variables. Three successful trials were filmed for each performer resulting in a minimum of 24 recorded kill shots. Precision motion analysis of high speed cinematographical data enabled determination of linear and angular displacements, velocity, and centers of gravity. Computer facilitation techniques permitted rapid data reduction. Descriptive statistical procedures were used to compare relationships for all three levels. Results indicated that higher level performers consistently develop ball velocities ranging between 104 and 123 mph ($\bar{x}$=112.9 mph). Velocities drop 36.9% when examining performances at the lowest level. Comparison of the mean values for ball height at point of racquet contact showed that the 'A' players hit the ball 38.4% lower ($\bar{x}$=7.95 inches) than the 'B' players ($\bar{x}$=12.91 inches), who in turn hit the ball 30.9% lower than the 'C' players ($\bar{x}$=18.68 inches). Stride lengths for the 'A' players were 12.3% longer than 'B' and 'C' players. Ball projection angles were similar for all three levels. However, angle of the racquet face at point of ball contact resulted in 'A' players hitting with a closed racquet face ($\bar{x}=-1.85^{\circ}$) while the 'B' and 'C' level players hit with an open racquet face ($\bar{x}$=+4.69 and $+9.39^{\circ}$ respectively). Center of gravity height was slightly lower proportionately for individuals developing greater velocity. In addition these same players strike the ball closer to a position directly opposite their vertical line of gravity. Implications of these findings for coaching/teaching will be discussed.

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* This study was supported in part by a Faculty Research Grant from the University of Delaware. The authors are indebted to the Greenville Racquetball Club of Wilmington, Delaware, Rus Ruarck, manager, John Chelucci, professional and to the members who participated in this study.

The popularity of racquetball can be evidenced by the increasing enrollments found in courses in secondary schools, colleges and universities where this activity is a part of the instructional program. Other evidences of the popularity of this game are reflected in recreational use of facilities on campuses and Y.M.C.A.'s around the country, as well as the growing number of private racquetball clubs.

The method of teaching utilized in presenting the proper technique of hitting the forehand stroke, has varied from the presentation of a modified tennis stroke to an all-wrist action stroke. Teachers of the forehand stroke have gathered information from personal experience, self-analysis, conversations with other teachers and observations and discussions with high level performers. The composite information of how to hit a forehand kill stroke is founded as much in personal preference as it is in critical analysis of high level performers.

The purpose of this study was to examine and qualify the biomechanical characteristics exhibited by open level players (hereafter referred to as 'A' players), 'B' level players and Novice level players (hereafter referred to as 'C' players) while hitting the forehand kill shot and to assess the appropriateness of various teaching cues that are found in current technique books of racquetball.

Methodology

The racquetball players (N=12) were filmed through a plate glass wall in the natural environment of the racquetball court. The filming was completed by using an electrically driven, 16mm, high speed Locam camera (164-4DC) operating at 100 frames/second. Two banks of colortran (mini-brute 9) lights, set at 45° angles to the subjects, were used to provide sufficient lighting. A Hercules Tripod supported the camera 27 feet directly opposite and perpendicular to the center of the hitting zone in the racquetball court. The complete forehand kill stroke was filmed, from ball drop to completed follow-through of the stroke. The players were approximately 32 feet from the front wall when each trial was filmed. Each subject was filmed for three successful trials of the forehand kill shot.

The quantified precision analysis of high speed film was facilitated by using a Vanguard 16 mm motion projection head (M-16C) in conjunction with a Hewlett Packard Digitizer (9107-A). This permitted rapid and precise determination of "X" and "Y" coordinates for segmental points of the racquet, ball and body. This assisted in the application of the segmentation method (3) necessary for the determination of each player's center of gravity as well as height of the ball at contact with the racquet, ball velocities, angle of the elbow at the instant of racquet contact with the ball, angle of the face of the racquet at point of ball contact, length of stride in relation to standing height, distance of the vertical line of the center of gravity from the ball to the heel of the front foot. A Hewlett Packard Programmable Calculator (9100-B) both stored and quantified the cinematographic data.

The "Film Motion Analysis" computer program of the University of Delaware PLATO system (1) was used to provide rapid determination of centers of gravity along with linear and angular measures of displacement.

Each of the three skill categories contained four players for this study. Their physical characteristics are summarized by level of playing ability in Table 1.

Table 1

Physical Characteristics of Subjects

Level of Ability	Age		Height		Weight	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$ lbs.	S.D.
A (N=4)	29.75	3.95	5.92'	.18	176.25	17.50
B (N=4)	28.00	2.71	5.77'	.08	167.50	11.90
C (N=4)	30.75	2.36	5.84'	.15	168.75	12.50

There was no drastic difference in age between the three groups as they appeared to be quite similar. The physical characteristic of weight also was consistent although the 'A' level players were somewhat heavier. The height of the subjects required some consideration particularly in light of later discussions regarding the center of gravity of the players. The level 'A' players were slightly taller than the other players in the study.

Results

Comparison of the mean values of the height of the ball from the floor at the moment of contact with the racquet (see Table 2) indicates that higher level players hit the ball much closer to the floor with more consistency (less variability) than do lower level players. Level 'A' players hit the ball 16% lower than the level 'B' players and 72% lower than the level 'C' players. As is reflected in the examination of the ratios of height of the center of gravity to the standing height of the respective players, all levels of players maintained similar ratios while striking the forehand kill shot. However, since the mean height of the level 'A' players is greater, it indicates that higher level players drop their centers of gravity through a greater vertical distance before striking the ball.

Table 2

Ball Height and Ratio of Center of Gravity/Standing Height

Level of Ability	Ball Height		Center of Gravity/Standing Height	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
A	5.51"	2.03	.44	.03
B	6.57"	2.62	.42	.02
C	19.56"	4.27	.44	.01

Table 3 reflects the mean linear ball velocities following contact for the three levels of players. It was obviously anticipated by the investigators that higher level players would generate greater linear ball velocities than lower level players. This expectation was verified in the analysis of the films. The mean velocity of 'B' level players was 10% below that of the level 'A' players and 32% faster than the level 'C' players. Velocities drop 38.6% from level 'A' to level 'C' players.

Table 3

Ball Velocities, Wrist Velocities and Angles of Elbow at Contact

Level of Ability	Linear Ball Velocity		Angular Wrist Velocity		Elbow Angle	
	$\overline{X}$ MPH	S.D.	$\overline{X}^{o}$/sec	S.D.	$\overline{X}$	S.D.
A	126.68	12.16	2049.27	871.46	169.97^{o}	8.40
B	114.27	9.37	2213.34	1023.26	163.90^{o}	11.62
C	77.81	15.18	Not Available		160.37^{o}	13.11

The angular velocity of the wrist over a time span of .02 second prior to ball contact, indicated that the 'A' and 'B' level players are very similar in performance. Each group generated mean wrist angular velocities in excess of 2000^{o}/seconds. Data for 'C' level players were unavailable due to the height of the ball when the racquet struck it and the perpendicular location of the camera to the subject for filming.

An examination of the elbow angle of the swinging limb at the moment of contact indicated that level 'A' players hit the ball with a straighter elbow (3.6%) than do level 'B' players, who in turn hit with a straighter elbow (2.2%) than do level 'C' players. A drop in the angle of the elbow at the point of racquet contact with the ball from level 'A' to level 'C' players was 5.6%. It is important to maximize the elbow angle at the moment of ball contact in order to generate the greatest possible velocity in the struck ball.

The angles of projection of the ball from the racquet face were similar for all three levels. However, the angle of the racquet face at the point of ball contact resulted in level 'A' players hitting with a more closed racquet face ($\overline{X}$=+3.50^{0}) which represented a 4.5% increase over the level 'B' players ($\overline{X}$=+3.68^{0}) and 59% over level 'C' players ($\overline{X}$=+8.55^{0}). The level 'B' players were hitting with an open racquet face that was 57% closer towards a "square" position than the level 'C' players.

Examination of the data in Table 4 reveals that the ratio of the mean stride length to standing height for level 'A' and 'B' players was .56 for each group. As is indicated by the Standard Deviation however, the level 'B' players were not as consistent in their stride length as were the level 'A' players. The level 'C' players showed a mean ratio of .48 which is 14.3% less than that of level 'A' and 'B' players. The distance from the vertical line through the center of gravity to the point of ball contact by the racquet indicates that 'A' players hit the ball 60.6% closer to their center of gravity line than do 'B' players (means 1.35" and 3.43", respectively). The distance drops by 73.8% when comparing the highest and lowest values of the mean distance from center of gravity line to the point of ball contact.

Table 4

Width of Base to Standing Height, Center of Gravity Line to Ball Contact and Distance from Front Heel to Ball at Contact

Level of Ability	Width of Base/ Standing Height		Center of Gravity Line to Ball		Front Heel to Ball	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.
A	.56	.02	1.35"	1.36	1.13'	.58
B	.56	.13	3.43"	1.07	1.18'	.55
C	.48	.09	5.15"	3.42	.41'	.41

There was a 4.2% difference between 'A' and 'B' players in the distance measured from the front heel to the point of ball contact (means of 1.13' and 1.18', respectively). A difference of 63.7% was found between level 'A' and 'C' players in the distance measured between front heel and point of ball contact (means of 1.13' and .41', respectively). The difference between level 'B' and 'C' players front heel to point of ball contact, was found to be 65.3%.

Discussion and Implications

The higher level players participating in this study, have demonstrated that they have learned the lesson taught by teachers, professionals and technique books of the importance of hitting the forehand kill shot when the ball is very low to the floor (see Figure 1). In contrast, the level 'C' players are striking the ball at a much higher position of the ball. Shots that are hit from a relatively higher ball position and strike the front wall 6 inches or less from the floor, really are not kill shots as the angle of rebound is usually sufficient to allow the opponent a return of the shot. Successful kill shots appear to be struck close to the floor and hit the front wall close to the floor.

The ratio of the center of gravity to each subjects' standing height did not appear to be a major factor in the performance of the kill shot. All levels of players maintained very similar ratios and although the ratios are the same, standing heights of the players are different as a consequence, indicates that the better players tend to take a slightly longer forward stride.

Although the level 'C' players in this study are rated as "novice" players, they apparently have had sufficient playing experience to assume a similar hitting stance for each successive shot they were required to perform. Evaluation of this data indicates the importance of the teaching strategy that each shot attempted by the beginning player should be struck from the same relative position. When the forehand kill shot is being learned, whether the ball is dropped or lobbed off the back wall, the player should assume the hitting stance for each shot.

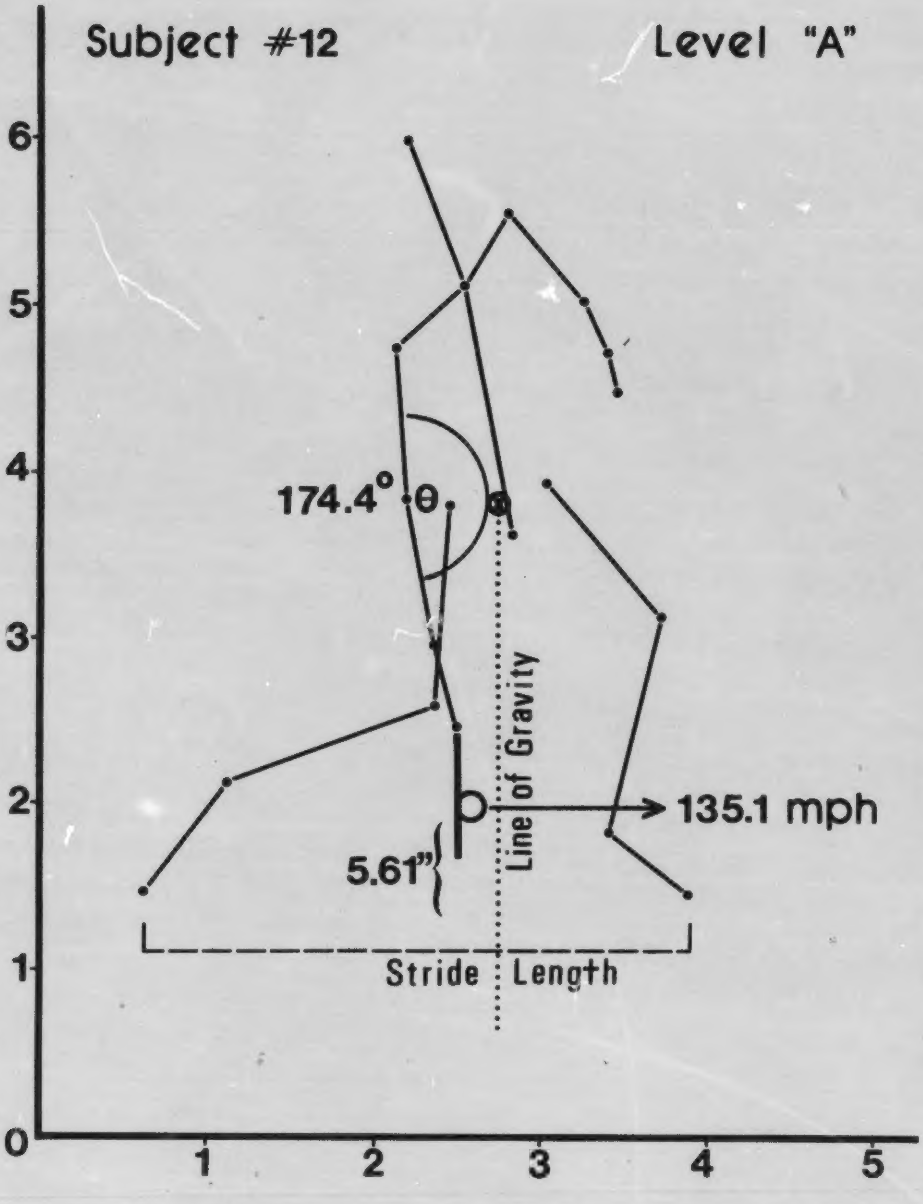

Figure 1.

Sample Computer Plot of Selected Kinematic Factors at the Moment of Ball Contact

The forehand kill shot, when executed with resulting high linear ball velocities, requires a very strong wrist action during the shot. Teaching this shot as a modified tennis stroke appears to be a disservice to the beginning player. The importance of making contact with the ball while getting full extension at the elbow appears to be meritorious advice for the beginning player. High level players appear more effective in lengthening the radius of their hitting stroke than low level players.

Teachers, professionals and technique books have encouraged that the angle of the face of the racquet at contact with the ball should be vertical (see Figure 1). The data in this study substantiated that contention. High level players more closely approached a vertical racquet face position while hitting than did the low level players.

The stride length of the level 'A' and 'B' players in this study suggests that a preferred stride length can be predicted for a beginning player. Both levels of players demonstrated a .56 ratio of stride length to standing height. Further verification of this ratio with larger groups of players is recommended before teachers and professionals demand a stride length that is approximately 56% of the beginning player's standing height. However, in response to the neophyte's request of what consistutes a good stride length, while hitting the forehand kill shot, a quantified response might be less frustrating than the trial-and-error method of selecting a stride length.

The center of gravity in relation to the player's base of support appears to be a very important consideration in analyzing the forehand kill shot. The high level players were not demonstrating the advice given in current technique books (2,4,5) of hitting the ball off the front foot. They were hitting the ball much closer to the center of gravity line than were the low level players (see Figure 1). In all calculations, the center of gravity was found to be just forward of the crotch and inside the left hip. This leads to a considerable distance to the left heel. The level 'C' players appear to be trying to do what they have read in books, and perhaps taught from a book by a teacher or professional, by hitting the ball closer to the front foot than the higher level players. Perhaps the higher level players have discovered by trial-and-error or peer analysis, that hitting from the middle of a solid base of support will likely yield a shot with a greater velocity. These results suggested that perhaps the better players are successful in spite of what is taught.

Summary

Within the limitations and scope of this study, the data would appear to support the following statements and conclusions regarding the forehand kill shot in racquetball:

1. Height of the ball from the floor decreases as the level of ability increases.
2. Successful players, all else being equal, strike the forehand kill maintaining a similar ratio of center of gravity to standing height for each attempted stroke.
3. Developing wrist snap in beginning players is a skill that should be emphasized by teachers and professionals.
4. During the hitting stroke, although the elbow is bent at the top of the backswing, higher level players have a straighter angle at the elbow than do low level players while making contact with the ball.
5. Hitting the forehand kill shot while concentrating on a vertical racquet face is a good technique for any level racquetball player.
6. The stride length appears to be a characteristic related to successful performance. High level performers have a higher ratio of stride length to standing height than do low level performers. Data presented in this paper suggests that a ratio of approximately .56 of standing height would be a good stride for the beginning player.

7. Hitting the ball directly opposite the center of gravity line more closely emulates the hitting technique demonstrated by high level performers rather than trying to hit the forehand kill shot off the left heel.

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PSYCHOLOGY

AND

SOCIOLOGY

A MULTI-PERFORMANCE LEVEL COMPETENCY-BASED INSTRUCTIONAL SYSTEM FOR TEACHING BADMINTON

by

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Abstract

The purposes of this presentation are: 1) to present a schematic diagram or model of a competency-based instructional system, 2) to show how a competency based, modular design instructional system can be developed for teaching badminton to all ability levels; 3) to report rationale as to how, to develop different performance competency levels; 4) to present how through the use of behavioral objectives, skill sequences can be devised to provide the learner with associated learning progressions, and 5) to present research implications of this type of an instructional system.

Visual aids and multi-media sources will be utilized to convey pertinent information to the audience. A sample competency-based module, including criterion-referenced differing performance level objectives will be shown in order to indicate the hierarchy between and within levels. Recording devices of peer- and/or self-recording systems will be presented and discussed, as well as statistical tools to interpret data collected.

This presentation will also be designed to provide information in regard to the adaptability of this type of an instructional system to all physical education programs, from the traditional to the individualized, and from the junior-senior high schools to the colleges and universities.

Competency-based instructional systems have immense value to educators, coaches, and students. This type of an instructional system is individualized, personalized, modularized, and can be computerized. By providing for various performance levels, the students are provided with the opportunity for self-paced learning and performance. This system further provides the learner with the opportunity to experience a beginning attempt toward self-awareness and self-discrimination of their own psycho-motor abilities, and introduces them to a variety of learning assistants to help them in achieving their own goal accomplishments. The teachers are provided with the opportunity to utilize a variety of teaching techniques and to accommodate students with differing learning and performance rates and styles.

The educational world has operated under the basic assumption that the students learn because of something the teacher does. According to Pease and Tabor (3):

> Too often this belief has resulted in teachers making decisions based on what teachers are supposed to do (role expectations) rather than considering how learners learn and making decisions accordingly. It appears logical that the first step in the process of producing a competent physical educator is to determine from research how learners learn sport skills. Once the knowledge is obtained, some inference can be drawn about how teachers of physical education should teach learners to learn sport skills (page 42).

My approach to you will be one in which I advocate the teaching of people. This implies that content is secondary to the persons that you are teaching or coaching. It also implies that you have some control over the learners and the learning environment.

When discussing individual skill acquisition, there are certain key questions that need to be researched and answered. Four of these are 1) What is the optimal number of trials necessary per skill for assessing a standard criterion? 2) How many skills can a student master per day? 3) Does a breakdown in execution of skills occur from an isolated performance to the performance in an actual game situation? and 4) If all skills are necessary for proficiency in game play, then how can not assessing the learner while executing all skills be justified?

Through the development of a competency-based instructional system, and evaluating the results, answers to the aforementioned questions can be at least partially obtained. Competency-based is centered on the specification of what constitutes mastery in any given subject matter field. The manner in which the competency level is communicated occurs through the application of specific objectives written in behavioral terms. Once the required behaviors have been established, they are sequentially arranged in a hierarchy from simple to complex. Following this, an instructional sequence to assist the learner to accomplish thetasks is planned. A test or check of some sort to determine if the required competency level has been achieved is administered once the learner determines readiness for a final evaluation.

Alternative ways of learning are provided for in a competency-based program since psychological reports have stated that different individuals possess different learning styles. The emphasis in a competency-based program is on achievement of specified objectives rather than on ranking the learners. Therefore, efforts are made to increase the probability of learner success by providing a variety of learning routes, from which the learner may select the ones most compatible with his/her own learning style. Student assessment is continual and ongoing rather than solely at the end of a certain specified time period. The results are visible and immediate. Because of this immediacy of feedback, the student should become more motivated.

An instructional system is composed of six main components. These six parts are: 1) conducting a needs inventory of what content should be offered, background and previous experiences and the level of your learners; 2) formation of learning objectives, 3) development of evaluative criteria; 4) analysis and sequencing of learning tasks; 5) design and implementation of the system, and 6) monitoring of performance.

The instructional system that I have developed is a multi-performance level competency-based instructional system for teaching badminton. A systems format, adapted from Banathy's model (1) was used as the means of presenting the competency-based program. A module designed by Houston, et al. (2), was used as the means of developing and organizing the multi-performance level competencies.

Twenty-one competency-based modules were developed used as the primary learning source for the students. The subject matter content was arranged into learning modules with each skill comprising a separate module. The modules were grouped into the following categories:

(1) shot execution
(2) Cognitive Development
(3) game play
(4) game play evaluation

(1) Sixteen modules were devised toward assisting the learners in mastering competency in shot execution; (2) one module was developed and directed toward cognitive development; (3) four modules were developed to assist the learners in the development of competency during game play; and (4) two of the game play modules were directed toward game play evaluation.

Each student was given a copy of each module, one at a time, and sheets for self-recording of skill attempts. All modules consisted of eight component sections:

(1) Rationale: A brief description as to the importance and significance of the development of the stated competencies as well as a description of the execution, and uses for the shot(s) during game play.

(2) Time Allotment: Estimated amount of time necessary for completion of each module.

(3) Pre-Requisites: Competencies the student must have mastered prior to beginning work or entering each successive module.

(4) Pre-Assessment: If the learner believed that he/she possessed the necessary skills and/or knowledge to demonstrate mastery of the stated competencies, he/she could request a pre-evaluation conducted by the instructor. If the student successfully demonstrated mastery, then the module competencies had been met.

(5) Level Objectives: The statements, written in behavioral terminology which clearly identified to the learner, the competencies to be mastered and demonstrated. Different performance levels are provided for, with the difficulty level increasing between and within levels.

(6) Instructional Activities: Learning assistants suggested for mastering competencies. Both multi-media and multi-mode sources were provided.

(7) Post-Assessment: Final evaluation, requested by learner, conducted by instructor to determine competency mastery.

(8) Remediation: Activities, and corrections outlined by the instructor designed to aid the student who could not master the level competencies.

A list of badminton skills and knowledges was formulated and grouped according to zone of origin. From this grouping, the skills and knowledges to be included were selected, organized and categorized by stroke association. The skills were then arranged sequentially for presentation, in a hierarchy from simple to complex. Each skill was then broken down mechanically into it's component parts, and each part was presented in the form of behavioral objectives.

The following modules were developed and utilized in the order of presentation:

(1) History: Designed to give a basic core of information relative to the origin of the sport, description for selection, use and care of equipment and description of playing surface.

(2) Footwork and Court Positioning: Development of body efficiency of movement and control, spatial and kinesthetic awareness of the body on the court and the shuttle.

(3) Short Serve Doubles: Execution and placement competencies.

(4) Receiving Short Serve Doubles: Receiving the serve with a variety of shots, court movement following each shot.

(5) Short Serve for Singles:

(6) Receiving Short Serve for Singles: Acquaint them with shots appropriate and mastery in executing.

(7) Long Serve Singles:

(8) Receiving Long Serve Singles:

(9) Long Serve Doubles:

(10) Receiving Long Serve Doubles:

(11) Modified Serve Game: Execution and placement of serves, receiving of serves, correct movement in a competitive situation, scoring during singles game play.

(12) Drive Serve:

(13) Receiving Drive Serve:

(14) Flick Serve:

(15) Receiving Flick Serve:

(16) Backhand Serve:

(17) Overhead Clear:

(18) Overhead Drop:

(19) Smash:

(20) Singles Game Play Evaluation:

(21) Doubles Game Play Evaluation:

Three levels of performance were provided for the learners in most modules and the level objectives contained both quantitative and qualitative components. Level I objectives were designed to assist the learner in the mastery of the basic mechanical components of the skill. They were the simplest objectives and were mainly basic unit in nature (containing only a single component or rote memory). Level II objectives were more complex and required the learner demonstrate performance master beyond the basic mechanical stages (convergent application - containing more than one component part in order to increase the difficulty such as accuracy, distance, speed, placement, consistency). An example would be (without all the fill-in wording) short serve module - serve 3-5 into the properly designated area, with the shuttle crossing the net top no higher than 12 inches.

Level III objectives were the most difficult to perform and required the learner to execute the skills in a more structured, yet sometimes divergent situations. More than one response could be appropriate, which meant that the learner had to be able to execute the shot possiblities, which entailed strategy choices which related to both cognitive and psychomotor mastery and were closer to the actual game play situations and choices. The last objective in each level was designed to be as close as possible to actual game play. It was hoped that by designing and structuring the learning sequence in this way that the size of the interval from isolated practice of skills to associated learning through practice combinations of shots to actual game play would be minimized.

Skill sequences were developed for those modules containing objectives devoted primarily toward mastery of shot execution. In order to develop an associated learning sequence, the rules of play and game strategy objectives were included in each appropriate module. It was hoped that through this sequencing, the total movement pattern would be developed instead of separate and segregated movements, which would result in a positive transfer to actual game play. Receiving objectives were included immediately following the serving competencies because it was determined as part of the restructuring that returning serves should be closely tied with the type of serve delivered.

Self and/or peer recordings were utilized as the main source of data collection. The students were asked to record the number of attempts at each level objective, and after five unsuccessful attempts to exit from the level objectives and follow the designed remediation path. This permitted self-paced and self-corrective learnings.

The data, collected through the three techniques of self- and/or peer recordings of the number of trials required to master their self-chosen level competencies and instructor evaluation were analyzed by (1) trials to criterion assessment through between group comparisons of means and standard deviation scores; (2) Pearson Product Moment Correlation Coefficient Techniques to determine if the relationship between selected psychomotor objectives and game play evaluations were significant.

The results of the data analysis revealed that badminton skills could be defined behaviorally and arranged in a sequential hierarchy from simple to complex and that a competency-based instructional system was a viable means for students to develop psychomotor and cognitive skills.

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Racquet Sport Participation Patterns
And Interests of Men and Women
Enrolled in Various Racquet Sport Courses

by

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Abstract

The purpose of this study was to examine childhood and adult racquet sport participation patterns of men and women enrolled in four racquet sport courses at the university level. Particular attention was on age and nature of introduction to racquet sports, whether participation generalizes to other racquet sports or is specific to one, and whether participation is recreational or competitive in nature. Some attention was given to sex differences in participation and the nature of introduction to racquet sports. In addition media interest in racquet sports and reasons for enrolling in racquet sport activity courses were examined.

How do individuals become involved in racquet sports? At what point during their life cycle? Do they learn racquet skills through formal instruction in the school or university, at a club, or do friends and family teach them informally? The search for answers to these questions involves the study of sport socialization. In addition, such answers concern the place of racquet sports in one's leisure time pursuits. What is fascinating is the fact that although these questions clearly identify research problems, there is very little information available in either the sport socialization or leisure literature which addresses these issues. In short we do not know very much about the means by which individuals acquire the necessary knowledge, skills, dispositions, and aptitudes to participate in the racquet sports. Furthermore, we do not know why individuals enroll in racquet sport courses, whether or not they have a history of previous participation, nor their anticipated use of learned skills for future leisure pursuits. These are all relatively uninvestigated topics. Therefore, the purpose of this study was to provide some descriptive information which may shed light on a few of these questions. Specifically, we examined childhood and adult general and racquet sport participation patterns of students who were enrolled in three racquet sport activities at the university level. We also attempted to determine whether racquet sport participation is an outgrowth of general sport involvement or whether it is a distinct type of participation.

We administered a fixed-alternative questionnaire to 117 males and 150 females (total N = 267) enrolled in beginning and intermediate levels of tennis, racquetball and badminton at the University of Illinois. Items focused on recreational and competitive participation during childhood and adolescence. In addition we asked the students to judge their ability as well as indicate which agencies were responsible for introduction to the racquet sports.

For some brief background about the students, they were predominantly white (90%), although there were some blacks (5%) and Orientals (3%). Forty-six percent of the subjects were Protestant, 32% Catholic, and 11.5% Jewish. Although all social classes were represented, the majority of subjects came from a middle class or above socio-economic background (low = 23%; medium = 39%, high = 23%). Only 11% of the students came from a background in which the parent or guardian had less than a high school education. Also, the sample seemed to be fairly representative of undergraduate students, as our subjects were enrolled in 24 different majors within several colleges or schools of the University. Twenty-three percent of the subjects were enrolled in beginning tennis, 23% in intermediate tennis, 22% in beginning racquetball, 22% in badminton, and 8% in intermediate racquetball. (This low percentage is due to the fact that fewer intermediate racquetball courses are offered compared to tennis and badminton).

When asked about current recreational time spent in playing the racquet sports, 77% indicated they played very little, if any, badminton; 99% indicated they never played squash; and 57% indicated they played little or not racquetball. In contrast 34% said they played little or no tennis. Thus, some recreational time is spent in the racquet sports, with the exception of squash, but the sport most likely to be played is tennis.

In their self-ratings of ability, 28% rated themselves above or well above average in badminton; 32% gave themselves a similar rating in tennis, and 25% in racquetball. In contrast 8% rated themselves as well below average in badminton, 7% in tennis, and 25% in racquetball. This blatant discrepancy in ability relative to racquetball should be more fully explained in a later section when we consider age of introduction to each sport.

Another interesting dimension of sport involvement is spectatorship or some form of consumption. However, it appears that these students are not fans of the racquet sports, as very few watch or read about them. Furthermore, the expected spectator racquet sport--tennis--was frequently watched by only 15%.

Relative to the importance of the racquet sports, we found some seasonal variation in participation, which may be a function of availability of facilities as well as climate. Specifically, only 7% rated badminton as number one during the summer; 13% rated racquetball in the "top spot;" but 76.5% rated tennis as number one. During the winter, however, there was a substantial shift; badminton was rated first by 21%; racquetball by 51% and tennis by 26%. The seasonal decline of tennis is quite noticeable, as is the substantial increase in racquetball during the winter.

Some of the most interesting results were the responses pertaining to sports in general and self-ratings of general sport skills. First of all, 58.5% indicated they participated in sport very much or to a great extent. In contrast, not one subject indicated that she/he had no sport participation whatsoever. Another extremely interesting finding is the fact that there were no significant sex differences in this participation pattern. Not only were these males and females general sport participants, but both sexes were highly skilled. When asked to rate their sport abilities, 67% indicated above or well above average skills when compared to others of their age and sex. Less than 8% rated their skill below average, and, again, there were no significant sex differences in these ratings.

Thus, some pattern seems to emerge--students in these courses are not beginners; they tend to be sport participants; and moreover they seem to possess an aptitude as well as a predisposition for general sport activities. Further support for this notion was found on an item which asked students to rate their level of interest in sports compared to racquet sports. Sixty-three percent rated themselves with high interest in both, whereas only 5% rated themselves as low on both. Thirteen percent indicated they had high interest in racquet sports but low interest in sport in general. Again, we found no significant sex differences.

Another question is whether or not their interest in sport influenced their interest in racquet sports. More than half the sample (53%) said they first participated in sport then became interested in racquet sports.

It could be argued that this finding is not especially surprising, particularly since the sport socialization literature suggests that some form of specilization typically follows generalized sport interest. However, this particular relationship is certainly worthy of more in-depth examination.

Some other interesting issues deal with reasons for enrolling in the activity courses and whether enrollment will increase leisure participation. Thirty-five percent indicated that they enrolled in their racquet sport for some form of fitness, health, or conditioning; 42% said it was for fun; while 10% wanted to learn skills; an additional 10% desired to improve their skills. Very few enrolled to fulfill a requirement (5%) or for some socially motivated reason (3%). Relative to future leisure, 17% indicated the course would greatly influence their participation in badminton, while 27% so indicated in racquetball. However, 40% said it would increase their leisure participation in tennis.

To help round out a profile of these subjects, we asked several questions pertaining to their introduction to racquet sports, their age of such initiation, and their general sport involvement during childhood. First of all, 72% indicated that their first racquet sport was tennis; 23% said badminton, but only 5% indicated racquetball. Of particular interest is the fact that 91% of the subjects were introduced to their first racquet sport by the age of 17. To add another perspective, 44% were introduced to badminton during elementary school; an additional 18% were introduced to it during junior high. In comparison only 25% were introduced to tennis during elementary school, but by the time they reached high school, this figure had increased to 57%. In contrast, only 32% had been introduced to racquetball prior to college. Thus, it seems that tennis and badminton are the racquet sports of childhood. On the other hand, racquetball seems to be a late adolescent sport, since less than 45% were introduced to it before the age of 18.

Another aspect of socialization into sport is concerned with where or how the initiation took place. The school is a major agency for teaching badminton; 52.5% indicated that's where they were first introduced to the sport. Although 28% of the subjects indicated they were introduced to tennis through the school, another 23% learned through some recreational or park agency, and yet another 28% taught themselves. For racquetball, 32% learned in the school (usually at the college level), while 18% taught themselves. It was in this dimension of socialization that we found some sex differences. It seems that girls learn badminton and tennis through the school more than through other agencies. Such is not the case for males, since they are just as likely to learn these activities in a recreational setting, through friends or by some other means.

Relative to childhood racquet sport participation, 13% indicated they played badminton recreationally, 18% played tennis, but only 1% played racquetball. Relative to their generalized sports interests as a child, 77% indicated that sports and physical activities were very important to them. Sixty-two percent rated their childhood ability above or well above average. Thus, the subjects in this study were not beginners, were not newly attracted to the racquet sports, nor were they unfamiliar with or unskilled in physical activity. Rather, they have a history of sport involvement, are probably highly skilled and had early introduction to at least two of the racquet sports. I think this profile is fairly accurate without drawing too much inference from the descriptive data. Although this is a rather superficial picture, the study does suggest many areas for futher study. In depth examination of the relationship between general sport interest and specific racquet sports is warranted. Further, comparisons between highly skilled racquet sport athletes and recreational participants in such sports might prove interesting. In addition some in-depth identification of specific agents who socialize individuals as well as the extent of tutoring might be fruitful. Although futher investigation into racquet sports as a leisure time pursuit is needed, there is a more important consideration for the school which offers and is basically responsible for teaching skills in physical activity, who really learns and pursues racquet sport skills? Who enrolls in elective courses? Who takes private lessons? The data from this study suggest we might be teaching those already taught. This notion needs to be closely examined because it has implications which may challenge our ideas about our clientele.

COACHING MALE AND FEMALE RACQUET TEAMS: ARE DIFFERENT APPROACHES NECESSARY?

by

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Abstract

Many racquet sports instructors face the dual responsibility of coaching men's and women's teams. At the intercollegiate and interscholastic levels, the coach's approach to the different teams may have a crucial impact on the team's success/failure.

Physiological differences that are real and apparent exist between male and female tennis and squash players. A comprehension of these differences dictates a flexible coaching philosophy and methodology. Less manifest, yet more salient,are the psychological and socio-cultural dissimilarities that require different coaching techniques.

Governmental legislation (Title IX) has had a tremendous influence on scholastic and collegiate athletics particularly women's sports. This law places a special burden on the coach of men's and women's teams. The coach must be sensitive to the needs and requirements of the law and aware of inequities or inconsistencies which could be construed as disparate treatment toward one sexual group.

Do male and female racquets' teams require different coaching methods, techniques, and philosophies? In what ways do social, cultural, psychological, and physiological factors influence the tennis and squash coach and player? Can a racquet's coach succeed while maintaining different standards and expectations for males and females?

A successful coach in the racquet sports requires a thorough understanding of the similarities and differences between males and females. Many high schools and colleges employ the same individual to coach their tennis and/or squash teams. In addition, all teaching professionals work with both males and females. It is crucial for the racquet's coach to comprehend the physiological, sociocultural, and psychological similarities and differences between the sexes in order to achieve maximum development of talent. It is even more important to maintain equal expectations, standards, and treatment of both sexes.

While the physical differences between the sexes are more readily apparent and may affect teaching philosophies and techniques, it is the sociocultural and psychological factors that affect success/failure. The coach must be aware of the decline of sex role stereotypes within the last decade and must take an androgynous perspective of sport to gain the maximum potential from team members.

Tennis is one of the few sports where women have always participated and in which males and females have equal interscholastic and tournament opportunities. Many schools and colleges have had women's tennis teams for years though few schools have provided equal opportunities for the women's team. At Southern Methodist University in 1974, the nationally ranked women's tennis team practiced on the intramural courts when not used for the intramural program, cancelled some matches for lack of funding, had access to the trainer only at 8:00AM, and provided most of their own equipment. Conversely, squash is one of the last bastions of male supremacy. It has recently become an intercollegiate sport for women in many colleges in the East, and women have been permitted to join public and some private squash clubs. Nevertheless, compared to men, few women enter college with a squash background. This alone often necessitates a different coaching approach. In both sports, the coach must be conscious of the differences that exist between and amongst the sexes yet maintain similar approaches and expectations.

Title IX supposedly eliminates sex discrimination in educational programs.[1] It has been the major impetus for the expansion of women's interscholastic and intercollegiate athletics even though the United States Department of Health, Education, and Welfare has yet to finalize implementation guidelines. This act has affected women's sport in America more than any previous invention, discovery or governmental decision. It has revolutionized American sport by encouraging participation of women and by making American society aware of the female athlete. At the same time, it has placed the coach of male and female teams under close scrutiny lest there be indication of disparate treatment. Numerous problems may result if a coach treats team members differently or if athletes perceive unequal treatment or opportunities.

Strength, speed and agility are crucial in the racquet sports. Differences in these characteristics exist among all individuals as well as between the sexes. Generally, males are quicker and stronger than females. Males possess greater strength, have a lower heart rate and higher aerobic capacity than females. Consequently, males generally hit the ball harder and cover the court better than females. Regardless of physical characteristics, training and conditioning philosophies should be similar for both sexes. Emphasis should be placed on aerobic and anaerobic training aimed at improving endurance, court quickness, and agility. Expectations and desires of the coach should determine the extent and variety of the training routine with flexibility serving as a guide. Those athletes who are relative beginners require more extensive tutelage on racquet techniques and skills than more advanced players where conditioning (of body and mind) may be crucial. This is particularly pertinent to squash where previous instruction and competitive experience varies widely.

Physical traits often determine the style and play of a tennis or squash player. Understanding the differences in strength and power should lead to flexibility in coaching and teaching. Whereas the coach may encourage and promote a power game in tennis as best for some females as well as males, this technique may prove harmful if an individual lacks the required physical attributes. A stronger male may develop a power game (serve and volley) while a smaller player (male or female) would be more effective with a baseline game and the ability to play net when the opportunity arises. Also, high school and college tennis players of both sexes should be taught proper doubles strategy and tactics with an emphasis on net play and aggressive volleying. Females are capable of player power doubles if they are taught properly and continually encouraged.

In squash, the teaching techniques, strategy, and tactics for both sexes should be comparable with emphasis on compact strokes, depth and width on the ball, and crisp shots. However, the different physical attributes of the sexes mandates the style of play. Jack Barnaby (2) explains:

> Since women (with some but not many exceptions) cannot get much speed on the ball, they should use height on their drives far more than men. The ball will then go deep unless it is very feeble indeed. They should imitate the men's tactical objective, not their means of doing it, since that requires a degree of power that most women just don't have.

The pace of the game may be faster for males than females but the tactics, style of play, and strategy are similar.

Conditioning is crucial in the racquet sports. A rigorous training routine is important for the female and male racquets athlete. Emphasis should be placed on improving endurance, flexibility, strength, and systemic functions. More than practice and play is necessary to attain peak physical condition for the competitive tennis or squash player. Males may complete the same conditioning drills more quickly, but females are as capable as men of rigorous exercise. Cultural factors and sex role standards are primary reasons fewer females than males approach their physiological limits. According to John Lawther (6), "Women do not drive themselves as close to their physiological limit as men do...the gap between psychological limit (what one feels he can do) and physiological limit (one's actual physical and physiological maximum of performance) is greater in women than in men." Weight, circuit, and/or nautilus training programs may be instituted for males and females to improve their strength, speed and quickness. Although training routines may reduce disparities between sexes in various physiological capacities to perform exercise, it will not eliminate these differences. Furthermore, the coach must realize, despite myths to the contrary, "the development of strength in the female can be accomplished without a loss in femininity" (5).

Different socialization processes for males and females in American society and sex role myths and stereotypes that have developed through the centuries (of a physiological, social and psychological nature) have a profound impact on the athlete and the coach. A coach holding sexist views or supporting various antiquated attitudes will likely encounter numerous problems with team members: "their low expectations for women may limit the individual's capacity to perform to full potential both by affecting the athlete's own cognition and performance, and by denying them sufficient opportunities to perform" (9).

Until recently, sport was presumed to be male's domain. At the first Olympic Games in ancient Greece, 776 B.C., females were excluded as participants and spectators. Women have been encouraged to participate in those sports in which they could demonstrate aesthetic beauty and grace without jeopardizing femininity or sociality. As a result of the women's liberation movement, governmental fiat, and sensitivity to human rights, females have become aware of differential treatment and have taken legal action to eliminate inequities and improper treatment: "Lawsuits challenging the male domination of sports may be the best illustration of female impatience with women's place" (1). Nonetheless, attitudes and behavior toward females have constantly reinforced existing fables. Eitzen and Sage (4) believe "sexism has been employed to socialize females out of sports and deny them equal access to the rewards of sport." Women are still socialized into roles that do not emphasize competition, aggression, sports hero worship, or achievement orientation. Oftentimes, myths and stereotypes are reinforced by the coach whose expectations and treatment of the male and female athlete are different. For example, a racquet's coach may believe females are less competitive and less motivated than males and will thus not work as hard to succeed. If this attitude is conveyed, players will likely lose their incentive. A vicious self-fulfilling prophecy may ensue reinforcing the coach's beliefs and providing females little opportunity to debunk the myths.

Sex role stereotyping begins at birth. Studies by Lewis (7,8) have demonstrated that sex typing occurs within the first years of life. Through childhood and adolescence the socialization process into sex roles continues with masculine standards serving as the norm. Males receive support for their athletic prowess, females criticized or labelled "tomboy" if they take an athletic interest. A familiar refrain about female tennis or squash players is that "she plays like a guy" or "serves like a man". In the teenage years, major social and cultural distinctions appear to further divide the male and female athletes. Athletics is praised for males and emphasized as a method of character development, educational and social advancement. Serious female athletes are considered aberrant; many become social outcasts for pursuing athletics. Prior to the 1970's, females had relatively few opportunities to pursue their athletic interests outside recreational high school activities. Even though females have a greater opportunity for participation and exposure to sports today, they are still handicapped by legends and superannuated beliefs regarding their abilities and interests. The successful coach must demonstrate an understanding of social conditions and the societal changes produced by women's consciousness raising and governmental legislation. The coach must support the expectations and desires of the men and women, comprehend the different socialization and sociocultural processes affecting the sexes, yet still treat the males and females in a similar fashion. Anything perceived as differential treatment will prove deleterious to the coach and the team.

Understanding the social, cultural, psychological and physiological factors influencing the athletes along with enthusiasm, dedication, and talent is crucial to success for the coach of male and female racquet's teams. Perhaps as important is the team members' perception of equal treatment. Any preferential treatment--real or imagined--will have negative consequences for the team and coach. Thomas' (11) famous dictum that situations defined as real are real in their consequences is certainly true for the racquet's coach. The perceptions of the players, who are extremely sensitive to the issue, may influence their motivational levels. If players perceive the coach as demonstrating disparate treatment, establishing divergent standards, and/or maintaining different expectations, they will likely lose their motivation and interest. Hence, the coach of males and females must make every effort to treat the players equitably thus undermining the pernicious myths and stereotypes that abound in American society regarding male and female athletes.

Socialization into sport, self-fulfilling prophecies, folklore, and perceived psychological differences influence the relationship between athlete and coach of a male and female racquet's team. American males are continually socialized into a competitive environment where achievement motivation, success-orientation, and aggression are praised. Conversely, few women experience the same socialization patterns, instead they are taught to be passive and demure, characteristics anathema to success in athletics. The result says Duquin (3) "of perceiving sport as an 'agent of masculine orientation', that is an instrumental activity suitable only for males, is that majority of females will not desire prolonged or serious participation in such an activity". Oftentimes, the coach supports and reinforces these myths and stereotypes resulting in disparate treatment or expectations that harm coaching effectiveness and team morale. Silberman (10) found that what a teacher expects of a student is what occurs. When the expectations of the coach is based on stereotypes and sex role standards of society, the result will be harmful to the athlete, team, and coach. Having had a few opportunities to demonstrate their competitiveness, drive, and achievement motivation, having inferior facilities and training, and receiving constant reinforcement that athletics and femininity are incongruous, it is a wonder that females have even begun to debunk some of the myths regarding their psychological unsuitability for athletics. It is not surprising that role schizophrenia, femininity diminution syndrome, and fear of success become part of the lexicon describing the psychological problems encountered by female athletes.

Competitiveness, drive, desire, and motivation of females in the racquet sports may not be as evident as for males. Females rarely express their emotions or demonstrate their frustration or anger such as verbal outbursts or demonstrative acts. It is rare to see a female throw a racquet or scream an epithet, all too often part of the male court demeanor. Yet, the woman tennis or squash player who gives her time and energy to practice and improvement is as serious and determined as the male, but has to overcome society's restrictions and legends that have traditionally denied her an opportunity in sports. The successful coach can employ the same motivational techniques with males and females which should focus on maximizing potential and pursuing excellence. Furthermore, the coach should have similar expectations for both sexes regarding interest, improvement, and achievement. One major force promoting attitudinal change has been governmental legislation, Title IX of the Educational Amendments Act of 1972.

Formulated in 1972, but still without complete implementation guidelines, Title IX has been the key agent in promoting and transforming women's athletics in the United States. Not only has the legislation brought the issue of women's sports into the public focus, it has led to major changes in athletics at all levels and to a new outlook and perspective on athletics in society. While permitting women the opportunity to compete and demonstrate their capabilities, Title IX has sparked debate from athletic departments to the halls of the United States Congress. A myriad of problems within the athletic domain have emerged resulting from sociocultural legacies, difficulty in destroying myths, and lack of expectations and interest by athletic administrators and coaches. It has placed the coach of both male and female racquet teams in a precarious position since any perception of disparate treatment is likely to unleash a deluge of criticism and accusations. Not only must the coach in this situation give equal time to females and males, he/she must treat athletes the same in regard to training, motivation, and interest as well as those easily distinguishable factors as practice schedules, meals and travel expenses, hotel accommodations, etc. It is here that the perception of the team members is critical for any inkling of differential treatment will result in problems and inculpations that may harm coaching effectiveness. By providing equal treatment and maintaining similar expectations and standards, the coach can be in the forefront of social change leading to a transformation in sex role typing and the debunking of myths and stereotypes.

The successful racquet's coach of a male and female team must understand the social, cultural, physiological, and psychological similarities/differences between the sexes and adopt a flexible, yet equitable teaching and coaching program. By destroying the folklore regarding women in athletics and society, the coach can serve as a harbinger of social change. Through awareness and sensitivity, the coach can gain respect of team members which is crucial to success. Any perception of differential treatment by team members will be harmful to coaching effectiveness.

To return to the original questions, the answer is complex, perplexing, yet relatively simple. No, there should be no difference in treatment, expectations, or standards. Yes, there should be an understanding of social, cultural and psychological factors influencing the athlete and of the physiological capabilities that _may_ require different teaching techniques and tactics.

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[1] The crucial section of the law (P.L. 92-318, 20 USC Section 1681, 1972) states:

> "No person in the United States shall on the basis of sex be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any educational program or activity receiving Federal Financial assistance...".

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THE CENTERED ATHLETE: AN EXAMINATION OF ALTERED STATES OF CONSCIOUSNESS AND PEAK EXPERIENCES IN THE RACQUET SPORTS

by

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ABSTRACT

This presentation will include a discussion and a demonstration of activities (characterized as right brain activities) which alter the consciousness of the athlete and appear to improve the possibilities for surpassing his limiting expectations; thus, achieving peak experiences in the racquet sports. The discussion will cover mental barriers, stress reduction, and concentration.

Specific exercises will be demonstrated in areas such as: visualization, mental rehearsal, Zen, meditation, breathing, and energy awareness. This presentation will be imbedded in tennis application, but transfer of techniques to other racquet sports will be emphasized as well as the broader generalized effects on personal lifestyle.

The purpose of this presentation is to explore the techniques available for Peak Experiences in the racquet sports. The discussion will cover the utilization of several processes which can be implemented to alter athletes consciousness; a phenomena which can produce profound results leading towards optimal performance.

Peak performances can most effectively be defined as a time when athletes perform beyond their expectations. Going beyond limitations of expectations can be seen as:

1. Heightened sense of perception;
2. Extraordinary clarity;
e. Heightened reaction time;
4. Precognition;
5. Feelings of weightlessness;
6. Feelings of well-being.

Going beyond one's expectations in the racquet sports can be seen often when a player plays better than he ever did before or perhaps when a player sustains a rally longer than he or she has ever experienced. The same peak experience mentioned has been substantiated by many athletes in other sports. Many football, basketball, baseball, and soccer players have claimed to be able to read a play before it occurs - often at a deciding moment of play! More than a few joggers claim heightened awareness of their environment after they have jogged five or six miles. Such sensitivity events are worth cultivating. Therefore, some suggestions are offered to exercise and develop for the racquet sports.

Avenues for Reaching Peak Experiences and Processes for Altering Consciousness

1. Breathing techniques; Controlled breathing is perhaps the easiest and most readily available tool for altering consciousness. Centering on breathing has many benefits: (a) it keeps the mind from wandering to external distractions;(b) it increases oxygen consumption; (c) it tunes you in to your own body rhythm (d) it is tranquilizing.

2. Mental Imaging: Through mental imaging you can use the powers of your subconscious to construct your realities. Using the techniques of visualization you can act out your ultimate experiences before you enter into your match. Using the powers of the subconscious will assist you in actualizing your peak experiences-on court.
3. Concentration in the Here and Now: Concentration is a valuable tool for most of life's tasks. In athletes it is a pivotal capacity. The ability to concentrate for long periods of time can be a racquet player's most valuable asset. However, there are certain major blocks to achieving and maintaining a good attention span. The three I am concerned with here are (a) the minds wandering nature away from the here and now (b) monotony vs. a need for varied experience (c) the sabotoging effects of too much analyzing and thinking.

Expanding Avenues Before You Start

To alter your consciousness before you start your match, first lie down and relax. Close your eyes and inhale to a count of eight and exhale to a slow count of eight. Remain relaxed for about a minute, and again inhale to a slow count of eight. Hold your breath to a slow count of ten and then slowly exhale to a slow count of eight. Relax for two minutes before you continue. Now sit up and keep your spine straight as you cross your legs. Inhale as you roll your head up and exhale as you roll your head down. Continue this process for two minutes and then reverse the direction of your head turn. Visualize that you are on the court and that you are ready to begin your competition. Think of a time when you played better than you ever expected. Give yourself a tennis or racquet sport role model that you can identify with. See if you can give a mind's eye rerun of one of his/her most memorable experiences. Now visualize yourself superimposed over your role model, moving with the same control and style as she or he.

After you have successfully visualized your ultimate sports experience, reopen your eyes and come to a sitting position. Place a ball in front of you and allow yourself to *see* the many dimensions of the ball. Look at the fuzz on the ball and read the label. Close your eyes and again see the ball through imagery. Open your eyes again and stare at the ball for two minutes. Close your eyes and relax for two minutes. Again open your eyes and see the ball. Now move your eyes to the right, up, to the left and then down. Finally, move your eyes to the left, down, to the right and then up. Close your eyes and then relax. This off-court eye drill has several benefits. It enhances concentration, controls fear and anxiety and strengthens eye muscles for competition.

Altering Your States of Consciousness and Surpassing Your Limits During the Match

Altering consciousness during the match can again be most easily tapped through the process of breathing. When the ball leaves your opponents racquet inhale. When you get ready to contact the ball, exhale. Breath control can be a great tranquilizer and on-court it can provide tremendous energy and power. The novice who feels anxious about his or her game responds typically by holding their breath when they feel most concern. Breath retention goes against the natural rhythm and flow of the body as well as making the muscles work much harder than is necessary. By holding the breath, we may lose as much as 40% of our power and can make the ball deviate from five to twenty-five feet from the intended target. This is true due to the unusually high build up of blood lactate acid which makes the muscles fight each other. Visual imagery can also be used to tap your sub-consciousness during competition. When playing groundstrokes, begin to use your inhale-exhale controlled breathing exercise. When you approach the net, or when you are ready to hit a winner, visualize a gust of wind trailing your exhalation. As you hit, exhale and image a gust of wind or strong breeze growing from your breath and driving the ball hard before it. To heighten your attention span and avoid monotony on court, allow yourself to become preoccupied with the ball. See if you can read the label or see the outer dimensions of the ball. Note the arch in the flight of the ball as it crosses over the net. Notice the number of feet the ball crosses over the net. Listen to the ball as it bounces or feel the ball as it makes contact with your racquet. During long points it may be difficult to keep your mind from drifting to boredom. To keep past and future thoughts at bay, give the mind a task (or entertain it if you will). Reciting a sound, word or phrase as focus for concentration can be extremely helpful. The procedure is much like a mantra in the manner of a T.M. meditator. For example, you may want to say - ball when the ball bounces on the court and - control as you make contact with the ball. Ball-control, ball-control, ball-control. In this process you will allow the repetition of the phrase to consume your consciousness.

Avenues For Reaching Peak Experiences During Training

The process of altering states of consciousness can also be applied to reaching peak experiences during physical training for the racquet sports. Running for endurance is hard work, frustrating and painful. What about the "inside job" where altered states enhances physique? To alter your consciousness in training, use the same techniques of breathing, mental imaging and concentration on the here and now. Just before you begin your run, lie flat on your back, close your eyes and take fifty deep breaths. Imagine yourself running gracefully along a forest path. Imagine an animal in the forest. Allow yourself to become that animal and run as the animal would run. When you start your run again, concentrate on your breathing. Count the first fifty inhale-exhales. Visualize that you are running as an animal or as an Olympic long distance runner. If you begin to grow tired, imagine a gust of wind at your back. Allow it to carry you foreward, With the wind's help, you don't have to expand as much energy. If your mind begins to drift, place your concentration on a tree or perhaps bring your runaway mind back to your breathing processes.

Conclusions

Techniques such as controlled breathing, mental imagining and concentration focusing allow players to control their thoughts and their body responses. Many of my students are able to control what once was called the involuntary nervous system (pulse rate, blood sugar, and blood flow to the extremities). Students who have attended Tennis Centering workshops have often noted marked changes in efficiency levels. A readily observable result has been the rapid progress from short rallies of, say, six balls to long rallies of one-hundred balls in as short a time span as thirty minutes. Peak experiences in training sessions have also been visible where many players are able to double their distance in the first workout. Surpassing one's limits through Centering leads to such peak experiences as heightened body control, increased clarity of the mind and a feeling of being at one with the environment.

References to consider

Books that are considered noteworthy in this field include:

(1) Beyond Jogging by Mike Spino (1977)

(2) The Inner Game by Tim Gallway (1976)

(3) Peaking Through Tennis by Don Burkett (1979)

(4) Powers of the Mind by Adam Smith (1976)

(5) The Psychology of Consciousness by Robert Ornstein (1975)

(6) The Ultimate Athlete by George Leonard (1975)

SPORTS MEDICINE,
BIOMECHANICS
AND
PHYSIOLOGY

The Eye and Racquet Sports

by

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Abstract

The role that the eyes play in the complex physical activities of the racquet sports cannot be over-emphasized. However, the factors influencing the use of the eyes in this area are less totally defined.

This paper will explore the factors involved in "keeping your eye on the ball."
They are:

1. Visual acuity
    a) Unaided
    b) "Best corrected"
        1. Glasses
        2. Contact lenses
            a) Soft
            b) Hard
        3. Presbyopia
2. Accommodation-blur vs. out of focus
3. Convergence
4. "Cue theory" of perception of visual space
    a) Monocular:
        1. Geometric-areal (Tyndall effect)
        2. Light and shade distribution (shadows)
5. "Perceptual vector analysis"
6. Rate of change of angular magnification
7. Stimulation of adjacent retinal elements
8. Surround

One of the most frequently used imperative sentences in the racquet sports is, "Keep your eye on the ball!" However, this simple admonition is an extremely complex interaction of the sensory system and the motor system. The visual sensory system is composed of the retina, optic nerves, lateral geniculate body, occipital cortex, and temporal and frontal cortex of the brain. The motor system is composed of the motor cerebral cortex, cerebellum, spinal cord, and peripheral nerves to the muscles, tendons, and joints.

The visual perception of a motion is one of the most primitive evolutionary responses. According to Johansson (1), "The eye has evolved to function essentially as a motion detection system." In newborn mammals, the sensitivity of the cerebral cortex to direction of visual motion is present from birth, while many other visual functions need environmental stimulation to develop (2).

What are the physiologic mechanisms which allow the visual system to selectively track a 7 cm (2 3/4") tennis ball as it leaves the opponent's racquet at a speed of 80-136 km/hr (50-85 mph) and traverses a distance of ± 23.79 meters (78 ft.) in a time period of 0.67 seconds (3), often against a confusing montage of colors and forms?

Briefly listed, motion perception and interpretation is dependent upon the following:

1. Visual acuity
2. Accommodation
3. Stimulation of adjacent retinal elements
4. Perceptual vector analysis
5. Ocular movements
    a. Convergence
    b. Saccadic
    c. Vestibular
6. Rate of change of angular magnification
7. Cue theory
8. Surround

I. VISUAL ACUITY

Visual acuity refers to the accurate focusing of an image on the retina and its subsequent recognition.

II. ACCOMMODATION

Accommodation (i.e., internal focusing of the image onto the retina by the action of the intrinsic muscles of the eye on the lens within the eye) does not occur if the object of regard is over 6 meters (20 ft.) away. Therefore, over 75% of a tennis court has been traversed by the ball before accommodation becomes a factor. Also, this movement is a slow (8-25 °/sec.) response (5).

Even the out-of-focus image of a person needing glasses does not stimulate accommodation if the object is beyond that range (4). However, from both the practical and theoretical basis, the clearest, sharpest image produced by corrective glasses or contact lenses undoubtedly aids in the racquet sports.

III. STIMULATION OF ADJACENT RETINAL CELLS

The light gathering structure of the eye, the retina, contains 126 million light-gathering cells (5), of which there are 120 million rods and 6 million cones. Two functionally distinct areas can be identified. The fovea centralis measures 0.25 mm and contains only cones. The fovea and surrounding 1-1.5 mm (approx. 5° visual angle) is the area of greatest visual acuity, with direct connections to the occipital cortex. The peripheral retina outside the fovea is capable of much poorer vision (in the 20/100 range) because of the relative lack of cones and also the numerous interconnections between sensory elements (e.g., party lines). When a person "looks at" something, he does so with his fovea.

Interestingly, although the fovea is most sensitive to fine detail in static objects and slow-moving objects, the peripheral retina is most sensitive to rapidly moving objects (2).

The individual retinal cells respond to changes in light energy as an image falls over adjacent cells. In the retina, there are cells which respond to the presence of light ("on" cells), to the absence of light ("off" cells), and others which are direction oriented, responding to light moving at specific rates and in specific directions. There are a high percentage of cells (approx. 80%) which have binocular representation, i.e., the amplitude of the cortical light response is increased when both eyes are stimulated simultaneously (6).

IV. PERCEPTUAL VECTOR ANALYSIS

As the flow of impulses pass from the retina through the optic nerves to the lateral geniculate body to the striate cortex where its visual contact (color, size) is interpreted, according to Mishkin (9), "This information to the pre-striate cortex and posterior part of the inferior temporal lobe where...recognition of previously seen images occurs. Finally, a recognized image is transmitted to the amygdala...where it may stimultate...fear or pleasure." Meanwhile, other impulses simultaneously flow to the oculomotor system (cranial nerves III, IV, and VI) as well as to the head-motor system (7).

V. OCULAR MOVEMENTS

The eye initially begins a rapid, sharp rotation of the eyeball (saccade) in order to keep the image focused on the fovea (60° /sec.) (8). As stretch fibers in the extraocular muscles begin firing, and after a delay of 20-40 milliseconds, the head begins to follow in the direction of the eyes. The vestibular (inner ear) nerves are stimulated by the head movement and the biofeedback mechanism is repeated. Instantaneously, a poorly understood mechanism of analysis of visual input, computation of eye muscle, neck, and head movement keep the object of regard on the fovea as the head and eyes move synchronously with the approaching object.

VI. RATE OF CHANGE OF ANGULAR MAGNIFICATION

As the ball approaches, it subtends a larger angle and stimulates more retinal receptors. This rate of change is an important factor in judgement of the speed of approach of the object.

VII. CUE THEORY AND SURROUND

There are various cues of "depth perception" and the location of an object of known size can be identified by these clues. Examples are 1) shadows, 2) the presence of a nearer object (the net) hiding a part of a farther object (the ball or opponent), 3) color variations and 4) binocular depth perception(10).

Surround refers to the psycho-social aspect of tennis. "Anticipation", "reading the opponent", knowledge of surfaces, racquets, balls, "toughness", etc.

In summary, the object (ball or shuttlecock) creates an image on the retina. Biochemical changes transmit electrical impulses to the brain, and bio-feedback mechanisms of eye muscles, neck and other muscle responses are initiated. This process is one of the most primitive, most essential, and yet least-well understood processes in the area of physiology. The critical role in the racquet sports is obvious, and it is hoped that this paper will provide a basis and reference for further understanding and research.

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BIOMECHANICAL ANALYSIS OF BALLISTIC VS TRACKING MOVEMENTS IN TENNIS SKILLS

by

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ABSTRACT

Many athletic skills can be classified either as ballistic or tracking movements. A preprogrammed control which triggers neural firings and irrevocably commits the body to a path of motion characterizes a ballistic movement. In tracking activities, the neuromuscular triggering relies on feedback from muscle, tendon, and skin receptors. Examples of ballistic motions include throwing events, such as the discus or baseball pitching. Rising from the floor into a pressed hand stand or the arm motion of the breast stroke typify tracking movements.

Top class tennis players were biomechanically analyzed to identify the type of movement patterns used. High speed cinematography and extensive computer technology were used to facilitate calculations of displacements, velocities, and accelerations of various body segments.

Results revealed that top class tennis players could be separated into two categories. The competitor who played "ballistically" was characterized by large accelerations followed by large decelerations of the various body segments. The transition from acceleration to deceleration occurred just before impact. The second type of player relied on muscular feedback to "track" the racket throughout the swing with minimal alterations in acceleration-deceleration patterns.

The tracking technique demonstrated significantly greater accuracy compared to the ballistic type. This accuracy resulted from the racket remaining normal to the path of the ball for a significantly longer path of motion than that observed in the ballistic movement. "Ballistic" tennis players lost some accuracy in order to gain power, however, fatigue can interfer with the normal coordination of finely tuned neuromuscular pathways. The "tracking" player sacrificed power for greater accuracy and can, therefore, sustain greater fatigue conditions with less deleterious impacts on stroking skills.

In describing the movement of a tennis player, we do not normally talk of the independent contraction of hundreds of thousands of muscle fibers. Instead, the particular movement (such as the forehand, backhand or serve) and often the speed of the movement is more usually specified. This suggests a general strategy of describing the control of movement in terms of selection from a relatively short list of activity modes and within each mode, specifying the parameters required to execute the movement.

In addition to the internal control of movement, the body must obey the physical laws of motion. The three factors underlying all human movement are force, displacement, and duration of movement. These parameters are equally important in human performance since, in all motor skills, muscular forces interact to move the body parts through the activity. The displacement of the body parts and their velocity are important in the coordination of the activity and are also directly related to the forces produced. However, it is only because of the control provided by the brain that the muscular forces follow any particular displacement pattern, and without these brain center controls, there would be no skilled athletic performances.

Recent neurological research has demonstrated that the brain performs differently depending upon whether the desired motion is slow or fast. It was found that the motor control centers reacted in one manner when slow and/or steady forces were required, but reacted quite differently when variable or quick forces were desired. Results showed that control signals from the brain are more closely related to rates of change than to force levels and for this reason the range and the speed of the activity have important carryover implications for skilled athletic performance. For instance, tennis requires intricate timing of the varying forces and this is a critical factor for hitting the ball successfully.

For most people a movement is a movement. Even for most of those who have written about them, skilled and unskilled movements are differentiated only in terms of their results. Performance classifications are grouped as "perfect" and "imperfect". In general, interest has centered on the practical results rather than on the analysis of the process of the movement itself.

Many athletic skills can be classified either as ballistic or tracking movements. The division of movements into either the ballistic or the tracking mode is based on the fact that the muscle actions are entirely different. In ballistic movements, the muscle groups do not contract against each other. Rather, the agonistic muscle group initiates the limb movement by contracting briefly and immediately relaxing so that the entire contraction pulse occurs in approximately one twentieth of a second. During the median part of the limb movement, both muscle groups are relaxed and the limb swings freely due to momentum. Then the antagonistic muscles act and contract until the end of the movement. A ballistic action, therefore, is a momentum movement. In contrast, a tracking motion, which is usually a slower movement, is a "controlled" form of movement with the antagonistic muscle groups continuously contracting against each other. If the strength of these opposing muscle groups balance, the result is a fixation of the limb. However, if the pull of one muscle group is stronger than the other, the limb moves in that direction slowly, with continuous re-adjustment of the two muscle groups.

The purpose of the present paper was (1) to determine the biomechanical characteristics of top class tennis players and (2) to investigate the nature of their movements, with respect to ballistic-tracking modes, of the forehand, backhand and serve.

Methodology

Cinematographic data was obtained both during tournament play and at a special filming session at the Coto Sport Research Center. High speed motion pictures were taken simultaneously from four cameras including an overhead view. The cameras were placed in planes orthogonal to each other to allow views from all angles. The film speed was adjusted to 200 frames per second. Films were taken of various tennis strokes including the forehand, backhand, and serve. These films were interpreted through several analytic techniques: Visual observation, frame counting, and computerized biomechanical analysis. Tables and graphs were generated to determine patterns of motion which characterized the tennis players' performance. The athletes utilized were Jimmy Connors, Ilie Nastase, Chris Evert, and Rene Richards.

For the computer analysis, the films were projected upon a translucent 36 x 36 inch glass screen. Joint centers of the body were digitized every frame for information of the location of each joint center of the body throughout the particular motion. This digitizing process involved touching the projected joint centers with a sonic stylus. The emitted sound waves were converted into X-Y coordinates and automatically fed into the computer. As each frame was digitized, joint centers were projected onto a graphic display screen and connected by lines to form stick figures. The complete movement was recreated in stick figure form on the screen where examination and corrections, if needed, could be made. This numerical information was subsequently analysed by computer to determine the parameters of motion. These motion factors included the angle of impact, range of movement upon impact, relative motion of the various body segments, as well as velocities and accelerations of all body segments.

The kinematic analysis provided the information to determine the differences between any ballistic or tracking motion of the athlete. A unique approach in this project was that the dynamic characteristics of the tennis skill were obtained utilizing the biomechanical data from the athlete as they performed under actual playing conditions.

Results

Figures 1 to 7 illustrate the total body motion profile for Connors, Nastase, Evert, and Richards for the forehand and the backhand. Figures 8 to 11 present the same swings from the top view.

Figure 12 illustrates the velocity curves of the hand, forearm, upper arm, and shoulder segments of Nastase's forehand from the top view. The racquet velocity from the top view is shown in Figure 13 where it can be observed that the head of the tennis racquet slowed before the impact. The same characteristic was noted for the hand segment, seen in Figure 12. The forearm, upper arm, and shoulders appeared to change modes from a ballistic type of movement to a "controlled" or tracking mode. In fact, the shoulder segment showed a constant velocity from Position 12 to 30 and then decelerated during Positions 33 to 42, that is, just before impact. It is interesting to note that the forearm was the only segment that did not slow down prior to the impact.

Figures 14 and 15 illustrate the velocity curves for the various body segments and the racquet for Nastase's backhand. The characteristics of the racquet velocity were similar to those associated with the forehand as were the magnitudes of the angular velocities. However, all arm and shoulder segments demonstrated tracking motion characteristics before impact. Analysis of the moment of force demonstrated a co-contraction of the antagonistic muscles. The upper arm produced a nearly constant velocity which indicates a controlled neuromuscular "program". The hand and the forearm demonstrated a ballistic effect at the beginning of the motion and switched modes to become a tracking movement just prior to impact.

Figures 16 and 17 illustrate Evert's forehand from the top view. The racquet demonstrated ballistic actions when the arm segments accelerated and switched to become a tracking movement prior to impact. The shoulder segment decelerated from Position 15 until after impact.

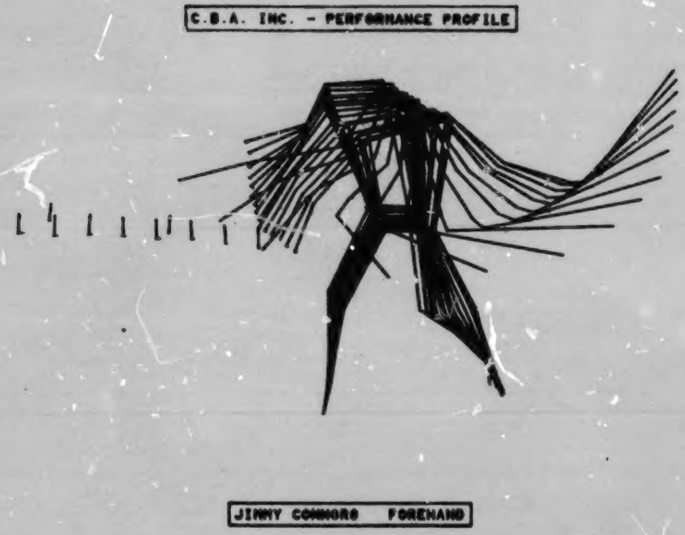

C.B.A. INC. - PERFORMANCE PROFILE
JIMMY CONNORS FOREHAND

Figure 1.

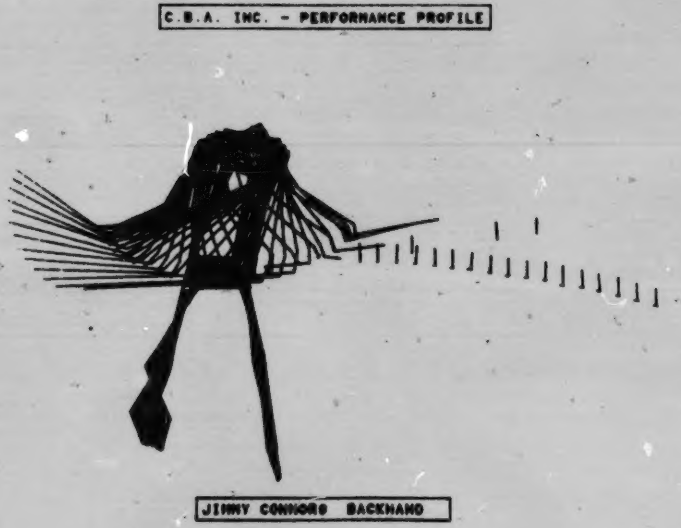
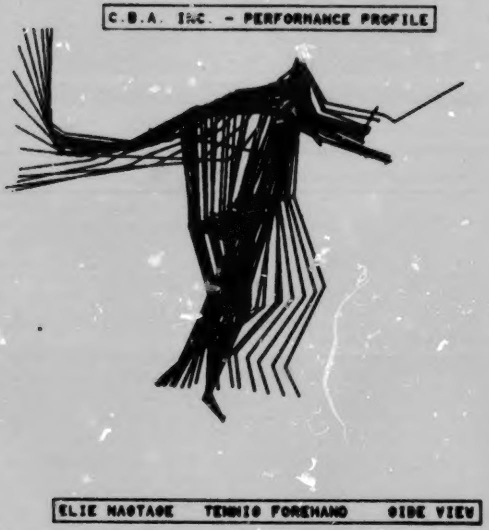

C.B.A. INC. - PERFORMANCE PROFILE
JIMMY CONNORS BACKHAND

Figure 2.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ELIE NASTASE TENNIS FOREHAND SIDE VIEW

Figure 3.

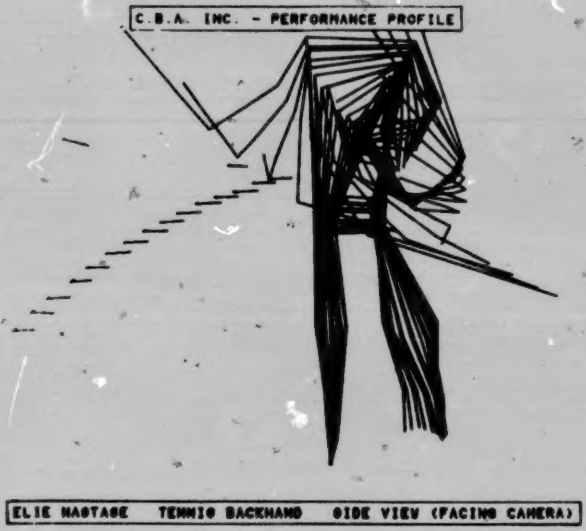

C.B.A. INC. - PERFORMANCE PROFILE
ELIE NASTASE TENNIS BACKHAND SIDE VIEW (FACING CAMERA)

Figure 4.

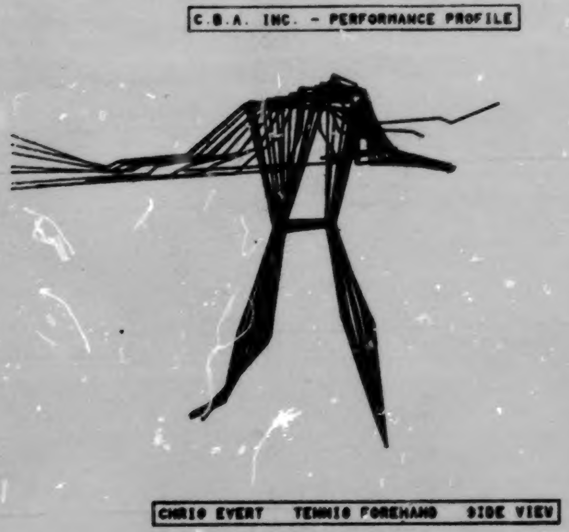
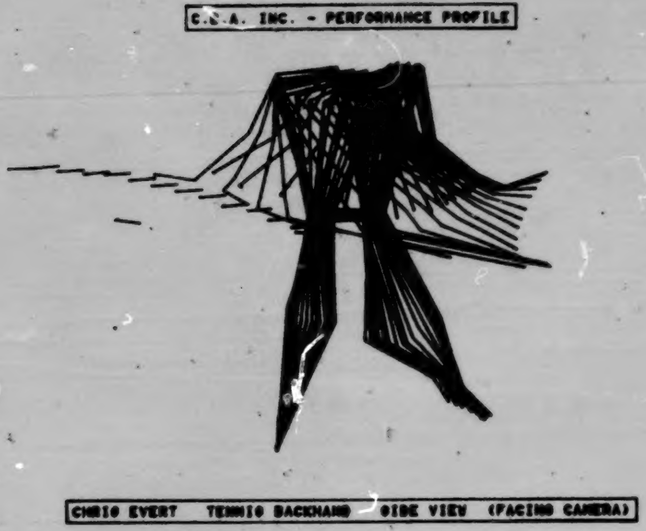

C.B.A. INC. - PERFORMANCE PROFILE
CHRIS EVERT TENNIS FOREHAND SIDE VIEW

Figure 5.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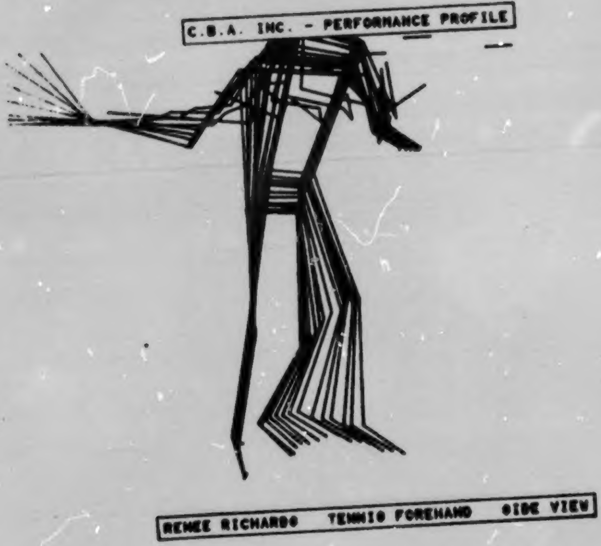
CHRIS EVERT TENNIS BACKHAND SIDE VIEW (FACING CAMERA)

Figure 6.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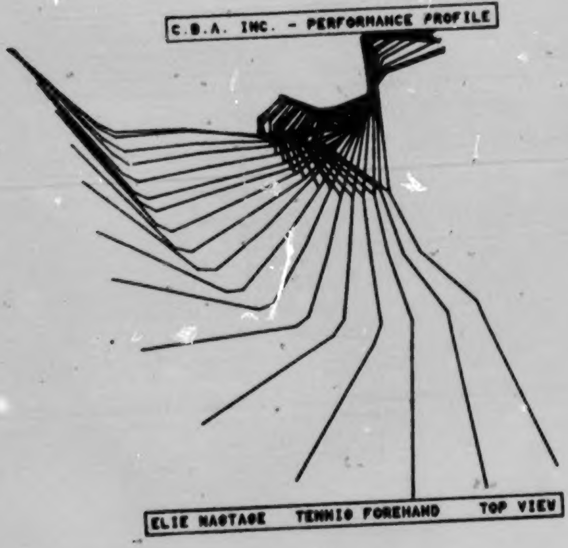
RENEE RICHARDS   TENNIS FOREHAND   SIDE VIEW

Figure 7.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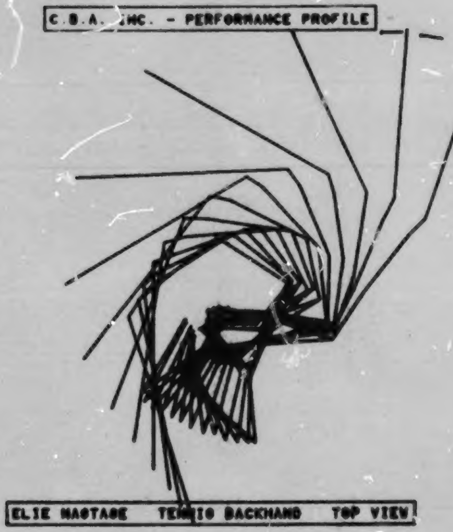
ELIE NASTASE   TENNIS FOREHAND   TOP VIEW

Figure 8.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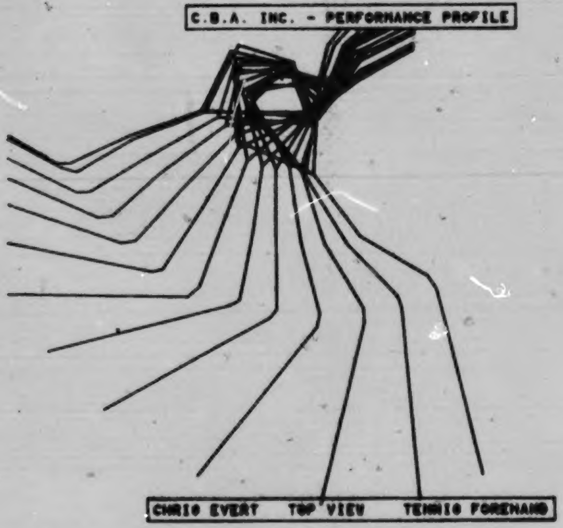
ELIE NASTASE TENNIS BACKHAND TOP VIEW

Figure 9.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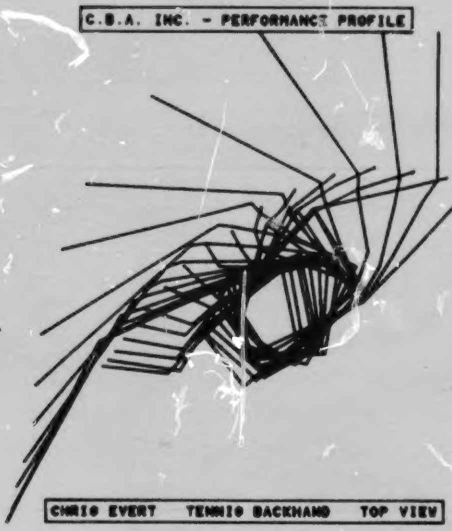
CHRIS EVERT TOP VIEW TENNIS FOREHAND

Figure 10.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CHRIS EVERT TENNIS BACKHAND TOP VIEW

Figure 11.

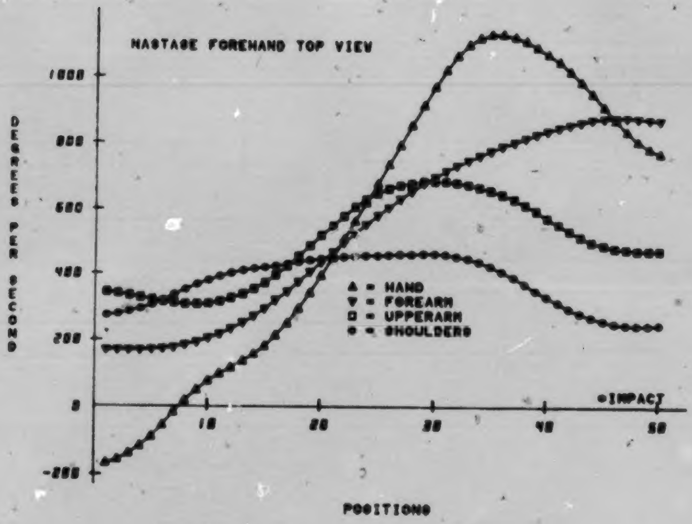

Figure 12.

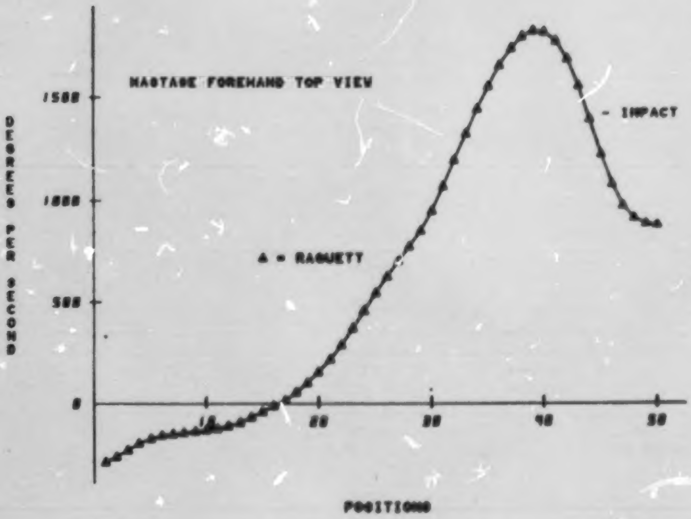

Figure 13.

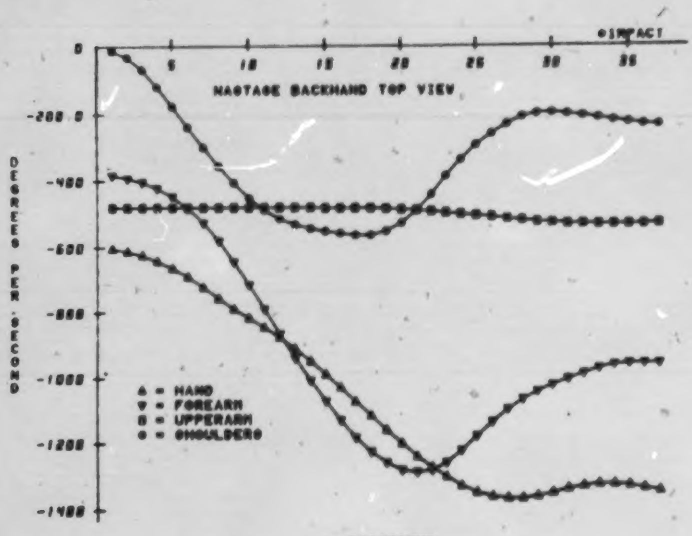

Figure 14.

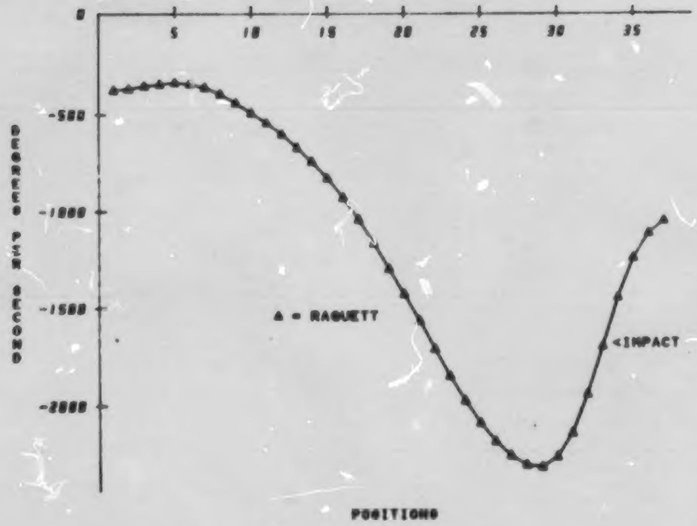

Figure 15.

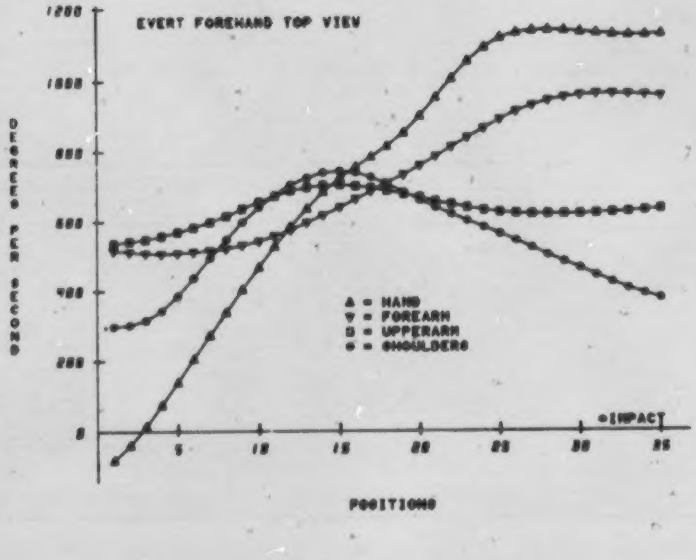

Figure 16.

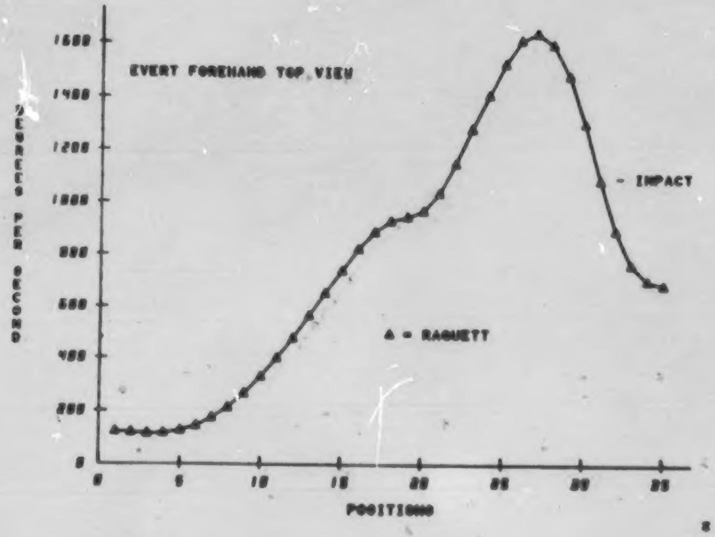
EVERT FOREHAND TOP VIEW
DEGREES PER SECOND
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
POSITIONS
- IMPACT
▲ = RAQUETT

Figure 17.

Figures 18 and 19 illustrate the velocity curves for the arm segments and the racquet in the backhand drive. Again the racquet showed deceleration before impact with the arm segments (the hand, forearm, and shoulders) switching modes just before impact into a tracking mode. The upper arm segment, on the other hand, was utilized ballistically and decelerated before impact without switching modes.

All analyzed players demonstrated a similar phenomenon with mode switching during the stroke by most of the segments. In some cases, however, a particular segment maintained constant velocity throughout the stroke. No player, however, demonstrated this mode-switching phenomenon during the serve.

A representative example of the body motion pattern of a serve is presented in Figure 20. The velocity curves for three of the players, shown in Figures 21 to 23, do not reveal the alteration of modes from ballistic to tracing. The serve, therefore, differs from the ground strokes and clearly conforms to the criteria of a purely ballistic action.

Discussion

The results of the tennis study demonstrated that there exists an "optimal domain" of movements. These movements occurred at several different levels when each segment acted at a different level. The muscles of each segment are organized into functional units and some of the groups appear to be preprogrammed for the purpose of performing a particular act. The similarity among the motion parameters for the various trials for the same particular tennis skill indicates that each body segment acted within the coordinated structure which governs that skill. The various segments work in harmonious coordination and, governed by the central nervous system, the sequence of movements needs little detailed executive control by the player.

It appears that the tennis players started their movements in a ballistic fashion where acceleration governs the movement and once the acceleration reached a particular value, there was a switch in modes and a tracking

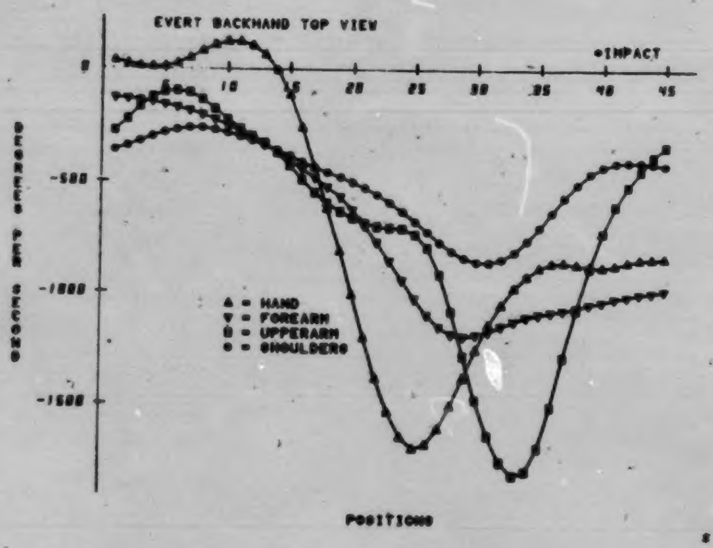

Figure 18.

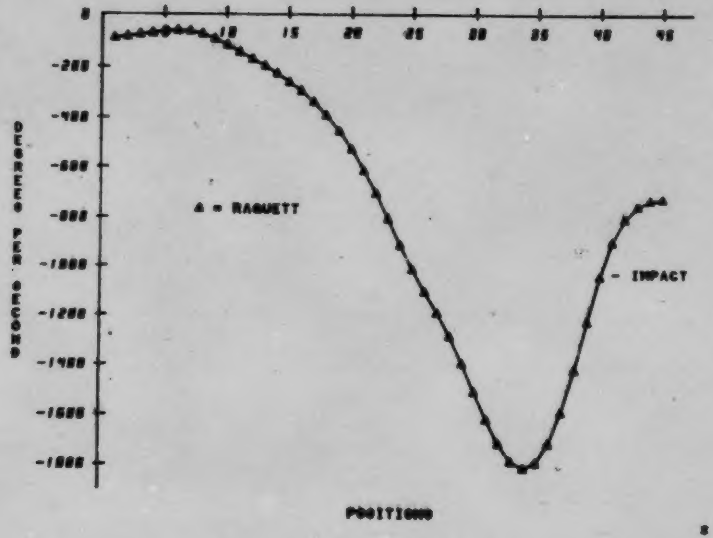

Figure 19.

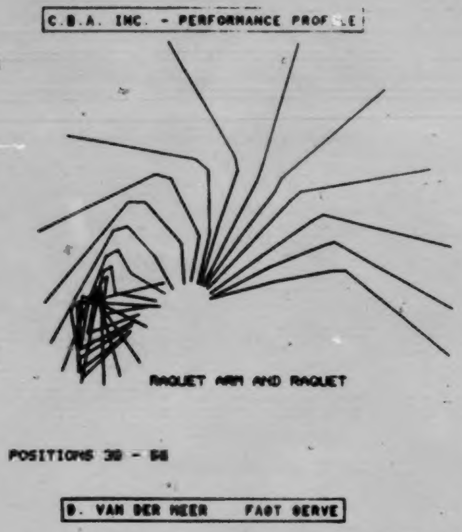
C.B.A. INC. - PERFORMANCE PROF LE
RAQUET ARM AND RAQUET
POSITIONS 39 - 56
D. VAN DER MEER FAST SERVE

Figure 20.

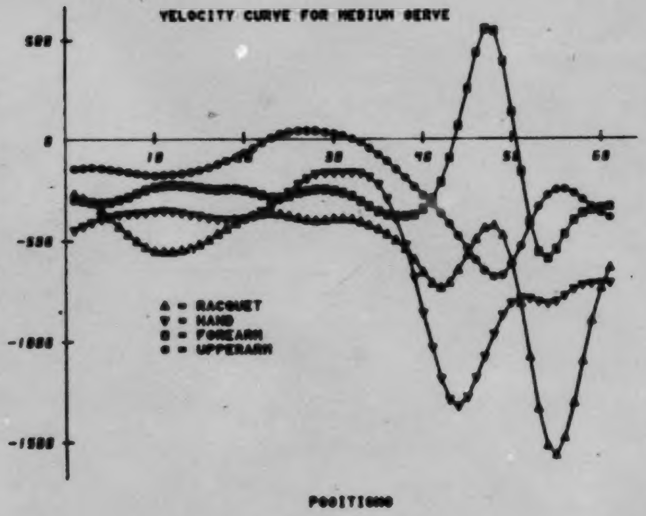

Figure 21.

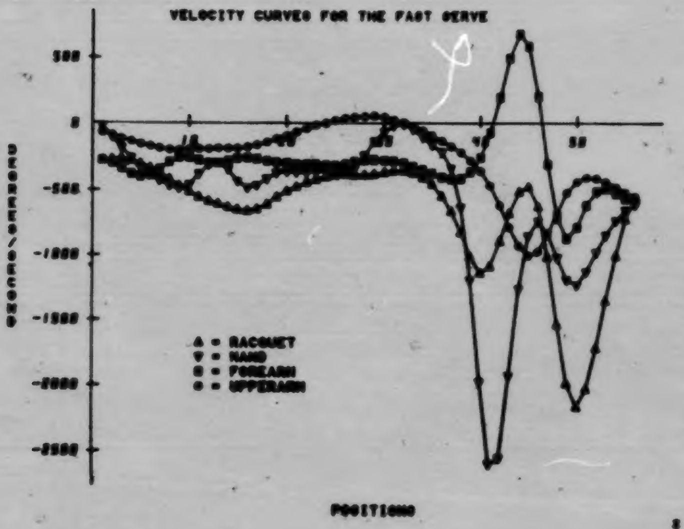

Figure 22.

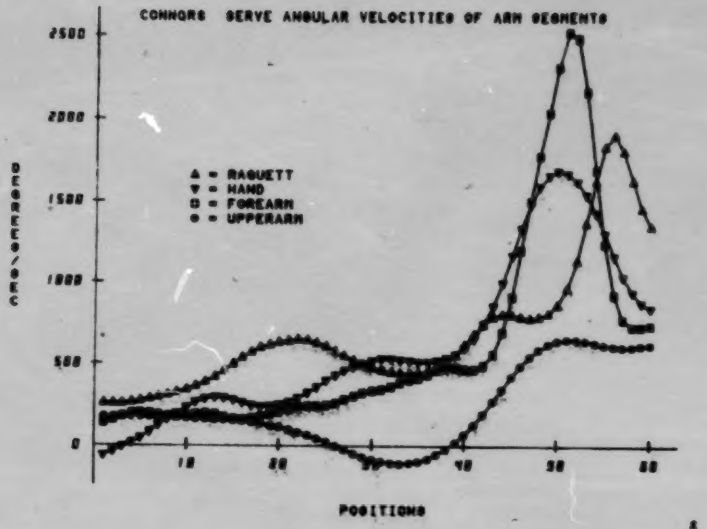

Figure 4

Figure 23.

was initiated. Tracking movements incorporate co-contraction of antagonistic muscles and permit greater control. Only in the serve did a ballistic type of motion predominate throughout with no changing of modes.

Most research on movement identifies ballistic and tracking movements. This study revealed that a combination of the two exists in highly skilled tennis players when the ballistic movement of the racquet is also accompanied by the need for accuracy.

The Tennis Serve As Compared With Overhand Throwing

by

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Abstract

Though the fastest service is not always the best one, the faster served ball is one of the key factors in winning tennis. An effective movement is the prime requisite for delivering a ball at high speed. The effective movement is performed through the appropriate sequence and timing in contraction of muscles involved. In the present study, the authors conducted a simultaneous electromyographic and cinematographic study on the tennis service in comparison with the similar movement, overhand throwing. Three Japanese men (aged 21-23) served as subjects. One is a highly-trained tennis player. The other two are untrained in tennis, but one of them is a trained baseball pitcher. Subjects performed the tennis services and overhand throws with the official balls. They were asked to do their best efforts. These motions were filmed from the side by 16 mm high-speed cinecamera (100 or 200 frames/sec). At the same time the EMGs were recorded on 7 muscles of upper arm and trunk. In addition the vibrational forces were recorded by the strain gauge attached to the racquet. Recordings of EMGs and motion pictures filmed by cinecamera were synchronized by a flash light.

The results showed the higher velocities of served and thrown balls for the trained subjects than untrained. Though the interindividual differences were found in muscle activities, similar muscle activities were observed between service and throwing in each subject. The interesting finding was the existence of silent period in muscle activities. Most muscles observed ceased their electrical activities during the service performed by the top tennis player and also during the throwing performed by the trained baseball pitcher. The duration of this silent period was approximately 300 msec, from 500 msec to 200 msec before impact or release.

Introduction

Though the fastest service is not always the best one, the velocity of the served ball is one of the key factors in winning tennis. An effective movement pattern is the prime requisite for delivering a ball at high speed. The effective movement is performed through the appropriate sequence and timing in contraction of muscles involved. Electromyography (EMG) is the best means to examine the muscular activities during movement. However, there are few EMG studies with the exception of Slater-Hammel (1949) on the movement of hitting the ball.

In the present study, the authors conducted an electromyographic analysis of the tennis service and compared it with the similar movement of overhand throwing. Simultaneously, movement patterns were filmed using high speed cinematography.

Procedure

Subjects: Three Japanese men, aged 21 to 23 years, served as subjects. One of them was a highly-trained tennis player (1978 Japanese intercollegiate champion). The other two were untrained in tennis. One of them however, was a highly-trained baseball pitcher who was a member of the varsity team.

Movements: Each subject performed a tennis service (flat service) with a wooden (hickory) racket (450 g) and a Dunlop Fort tennis ball (56 g). The serves were each subject's best efforts from the right side of the center line behind the base line into the left service court. After serving, each subject threw a baseball (150 g), using a legal overhand pitch, to the catcher who was 18.4 m from the subject. These movements were repeated more than ten times until a minimum of three to five successes in throwing and serving were achieved.

EMG recording: Electromyographs were recorded using bipolar surface electrodes (10 mm diameter) on seven muscles of the preferred arm and shoulder: m.trapezius pars transversa, m.pectoralis major pars sternocostalis, m.deltoideus pars acromialis, m.infraspinatus, m. biceps brachii caput longum, m.triceps brachii caput longum and m.flexor carpi radialis.

Electrical discharges detected by electrodes were led through fine wires to a pen-writing recorder (including bioamplifier). In addition to EMG, the vibrational force of the racket was recorded by a strain gauge (120 Ω) attached to the frame of the racket.

Filming: Each motion pattern was filmed by a 16 mm high speed motion camera (Photosonics 16-1P), which was located 12 meters from the subject. Film speed was 100 or 200 frames per second. The filming speed of the camera was determined by using a timing light generator, pulsing at a frequency of 100 Hz, and the linear scale was determined by filming a multiplier. Recordings of EMG and motion pictures filmed by the camera were synchronized by the flash light.

Results and discussion

Ball velocity: One successful trial from each subject (placed in the designated area in serving or within the strike zone in throwing) was selected for examination in each subject.

Ball velocity after impact in serving or release in throwing were determined from film. The fastest ball served was 41.2 m/sec for the trained tennis player and the fastest ball thrown was 32.1 m/sec for the trained baseball pitcher (Table 1).

Table 1. Physical Characteristics and Ball Speeds of the Subjects.

			ball velocity			
	age	height	served ball		thrown ball	
Tennis Player	23	168	41.2	(135.2)	25.7	(84.3)
Baseball Pitcher	23	175	30.0	(98.4)	32.1	(105.3)
Untrained Subject	21	160	24.2	(79.4)	27.3	(89.6)
	(yrs)	(cm)	(m/sec)	(ft/sec)	(m/sec)	(ft/sec)

The fastest throw observed for the baseball pitcher was similar to the data reported by Hay (1978) on thrown ball velocity for varsity pitchers. As for served ball velocity, the fastest serve obtained in the present study seemed to be reasonable, compared with data reported by Gray (1974) for the various tennis players.

EMGs in throwing: EMGs for the pitcher (left-handed) can be seen in Figure I. At about 1.8 sec before ball-release, as he lifted his right foot, electric discharges were minimal in all tested muscles. During the backswing, m.trapezius began to contract and m.deltoideus followed. After the disappearance of discharges in m.trapezius and m.deltoideus, the forward swing was performed. At the moment the right foot landed, large discharges were found in m.infraspinatus, m.biceps brachii and m.pectoralis major. Near the ball-release phase and afterwards, all muscles except for m.pectoralis showed the largest discharges.

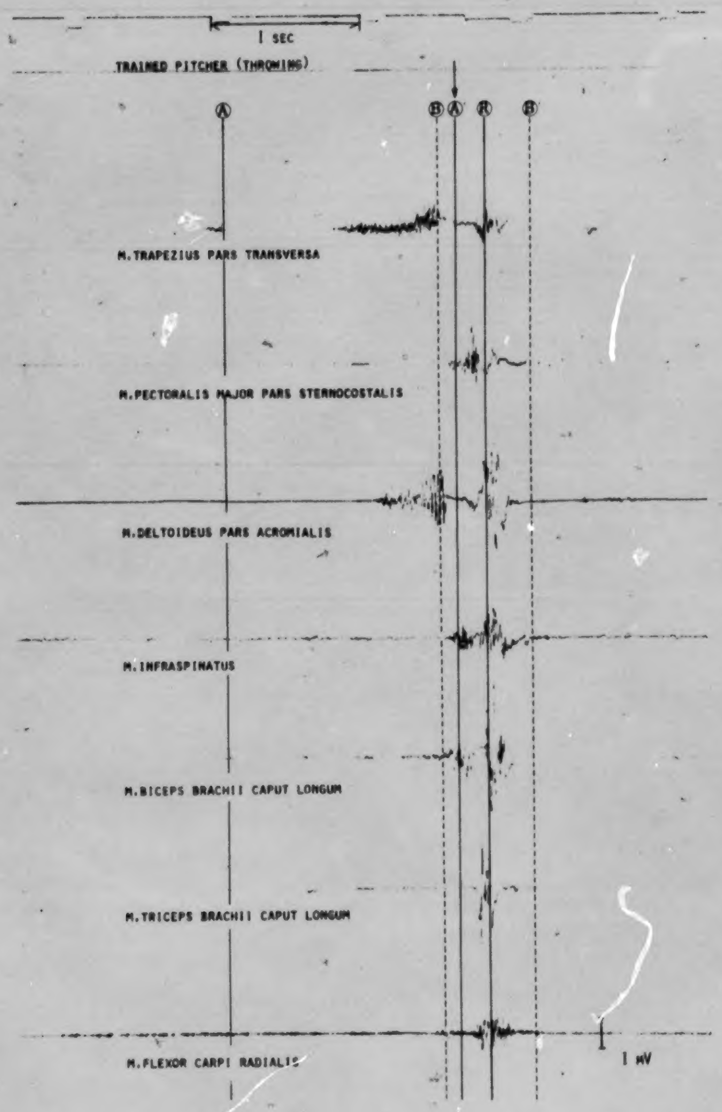


Figure 1. EMGs in throwing for the highly-trained pitcher.
A: instant of lifting the stride-foot
A': instant of landing the stride-foot
B: instant of beginning forward swing
B': instant of finishing forward swing
R: instant of release

Figure 2 depicts the EMGs in throwing for the untrained subject (right-handed). The duration from lifting the left foot to landing was relatively short (0.6 sec). During backward swing m.trapezius contracted and m.deltoideus followed. However, their electrical activities continued until the first half of forward swing. Namely, EMGs of m.deltoideus and m.pectoralis major overlapped each other, which was clearly different from the EMGs for the trained pitcher. Moreover, at the moment of ball-release, no discharge was found in m.trapezius and m.deltoideus compared with the pitcher.

Figure 3 illustrates EMGs in throwing for the tennis player (right-handed). In his case, EMGs were similar to those of the pitcher, except that m.trapezius contracted during the first half of forward swing.

EMGs in serving: The vibration of racket consisted of two different waves of low and high frequency. The wave of low frequency indicated slight bending of the racket and high frequency was initiated by the impact between ball and racket (Ohmichi, et al., 1978).

EMGs in serving for the trained tennis player are shown in Figure 4. He tossed the ball while swinging the racket forward approximately 1 sec. prior to impact. At that time, electrical discharges were found in m.trapezius, m.deltoideus, m.biceps brachii and m.triceps brachii. Thereafter, all muscle activity stopped except for the weak contraction of m.trapezius. Then a large discharge appeared in m.pectoralis major. Immediately before impact, the greatest amount of electrical activity was seen in m.trapezius, m.deltoideus, m.triceps brachii and m.flexor carpi radialis. The EMG of m.pectoralis disappeared following impact.

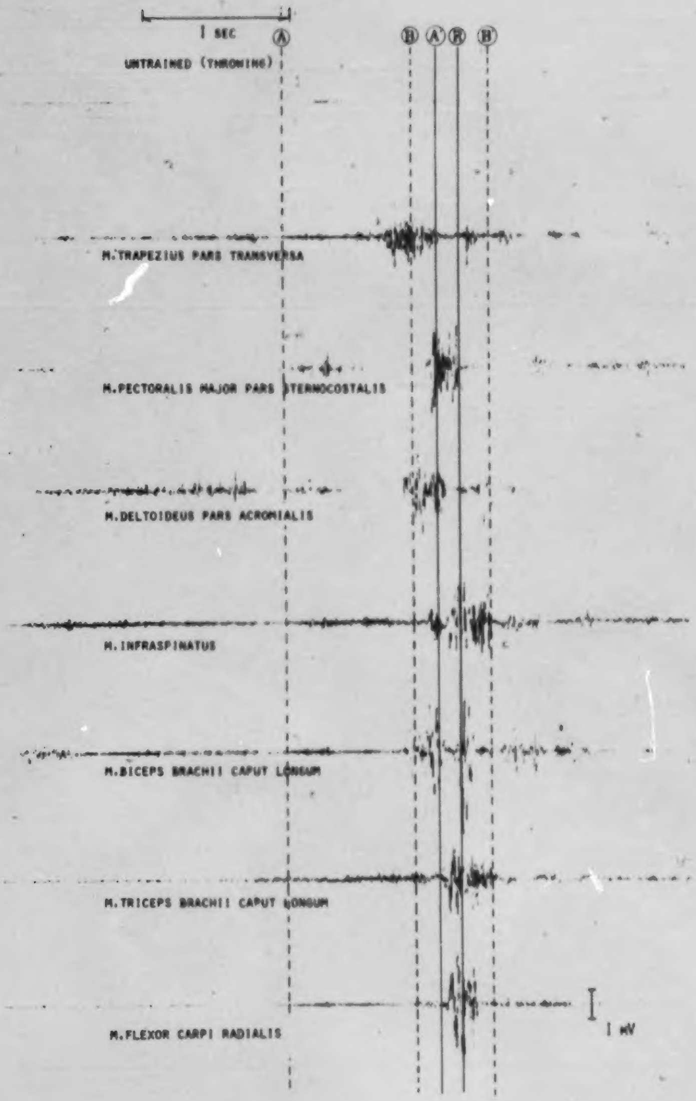


Figure 2. EMG's in throwing for the untrained subject.

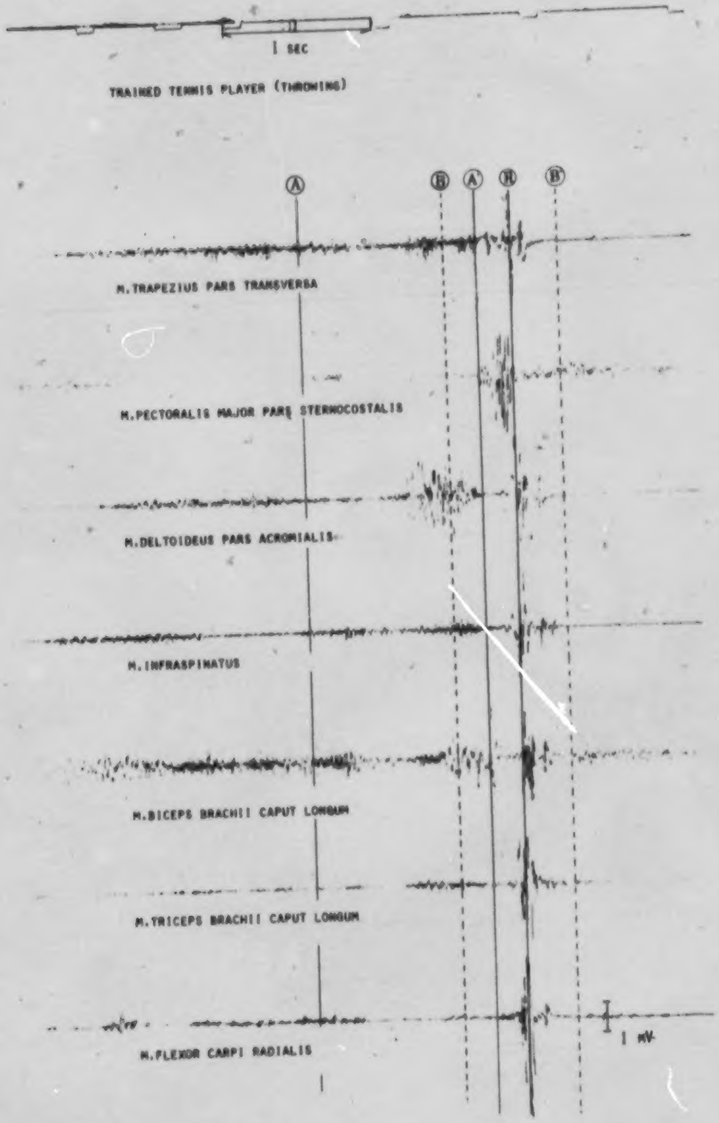


Figure 3. EMG's in throwing for the tennis player.

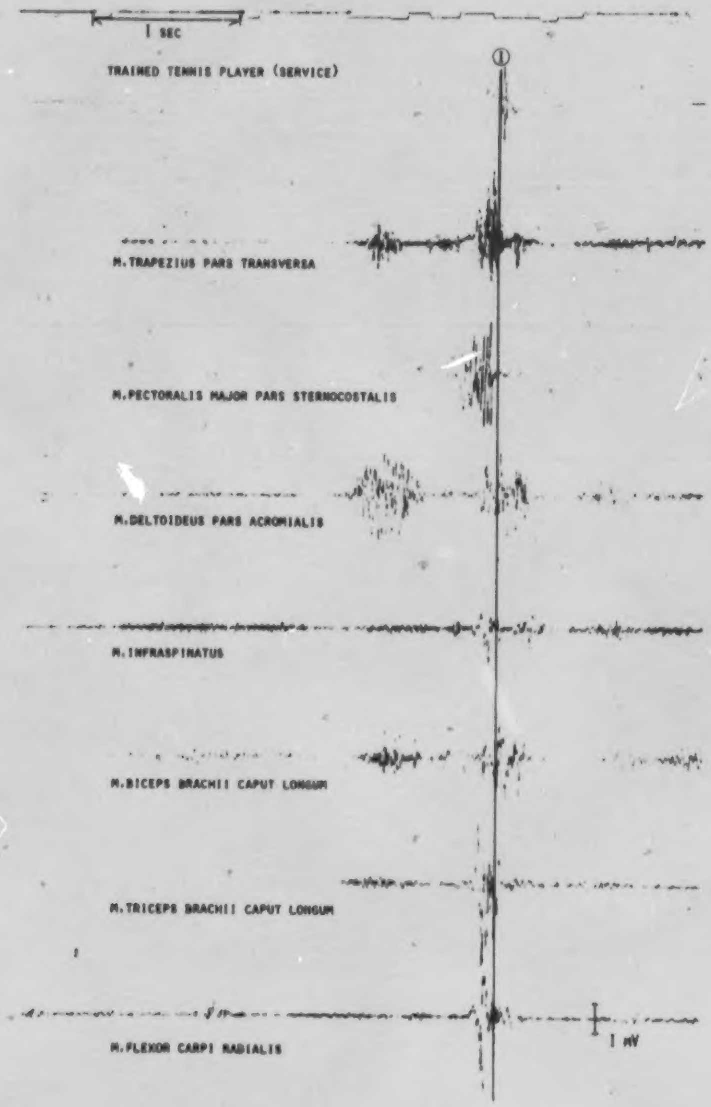


Figure 4. EMG's in serving for the tennis player.

Figure 5 depicts EMGs in serving for the untrained subject. There were clear differences in EMG patterns between the tennis player and the untrained subject. M.trapezius stopped electrical activity until the occurrence of impact and began contracting after the collision. Also, no discharge was found in m.deltoideus during impact. Other patterns in EMG for the untrained subject were similar to those for the tennis player.

Figure 6 represents the EMGs in serving for the pitcher. EMG patterns in m.trapezius, m.deltoideus and m.biceps brachii differed from those of the tennis player while other muscular activity was similar.

Body segments position: The body segment positions during throwing and serving were described from side-view pictures every 100 msec in Figures 7 and 8. In the present study, filming was conducted in one direction so a full discussion of the angular changes at each joint could not be completed. However, there were several definite differences in body segment positioning between the three subjects in both throwing and serving.

The most distinguishable factor was the relative position of the elbow joint in both movement patterns. The trained pitcher in throwing and/or the trained tennis player in serving extended at the elbow during the forward swing. Namely, the elbow was pulled forward and forearm was whipped forward and the wrist was flexed explosively.

EMGs indicated that the shoulder muscles contracted at the first stage of throwing and serving in all subjects. But the pitcher (in throwing) and the tennis player (in serving) stopped electrical

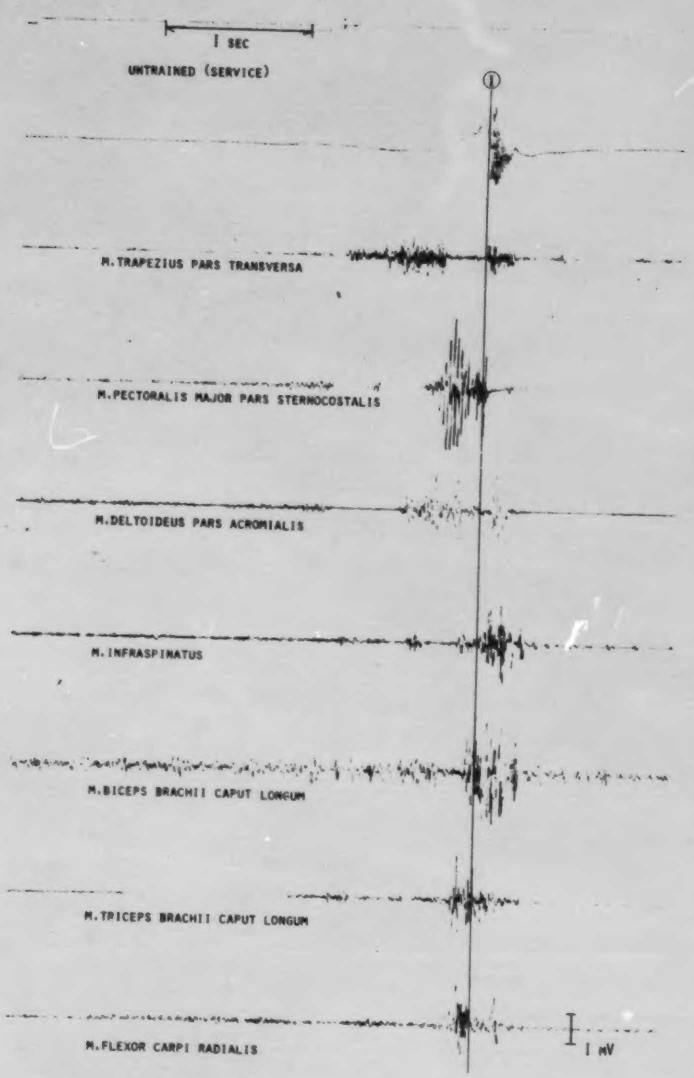


Figure 5. EMG's in serving for the untrained subject.

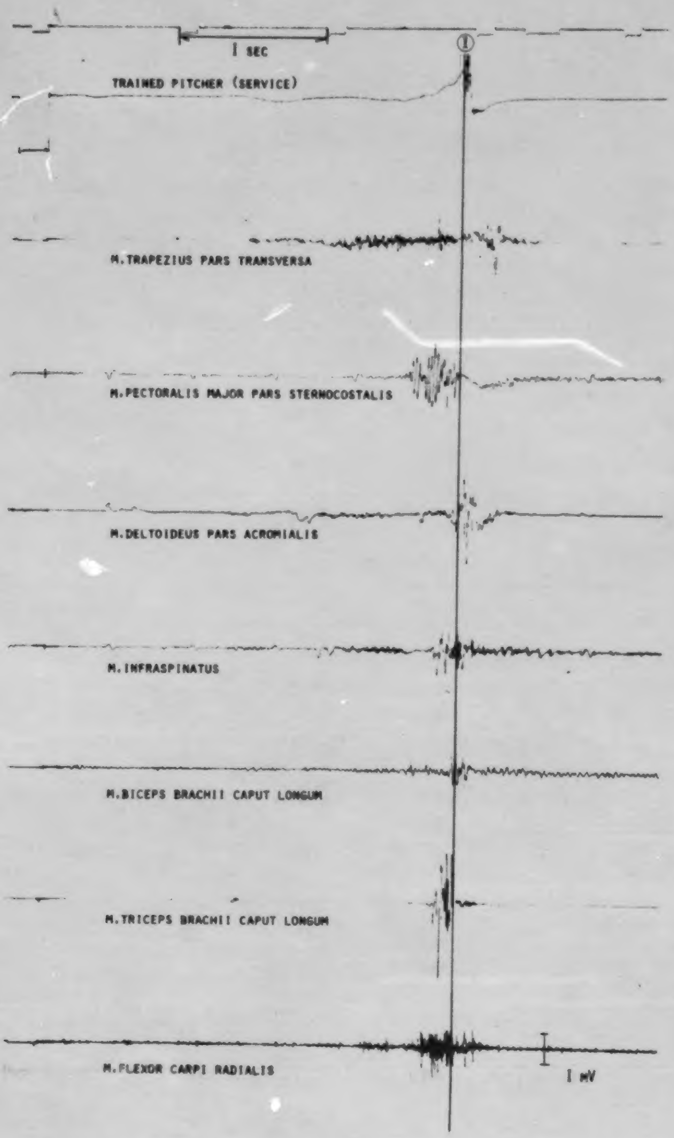
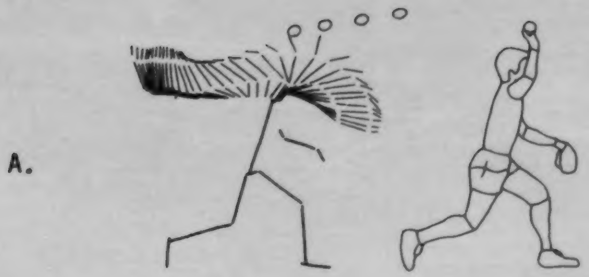
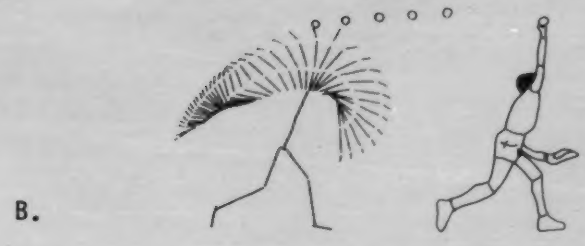


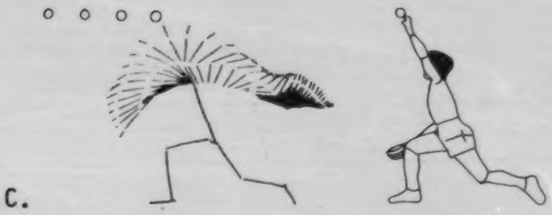
Figure 6. EMG's in serving for the highly-trained pitcher.



HIGHLY-TRAINED TENNIS PLAYER



UNTRAINED



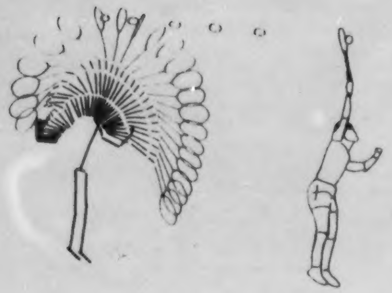
HIGHLY-TRAINED PITCHER
(SOUTHPAW)

Figure 7. Body segment position in throwing.

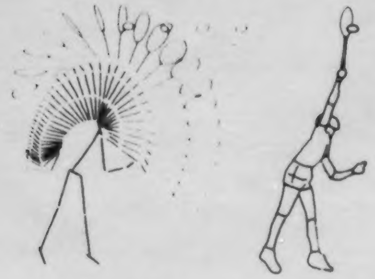
A. Highly-trained tennis player.

B. Untrained subject.

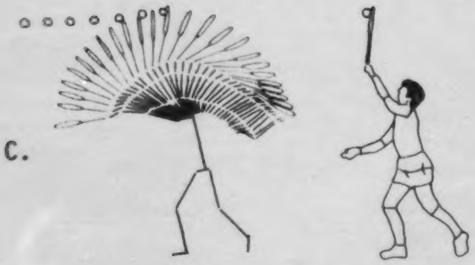
C. Highly-trained pitcher.



HIGHLY-TRAINED TENNIS PLAYER



UNTRAINED



HIGHLY-TRAINED PITCHER
(SOUTHPAW)

Figure 8. Body segment position in serving.
A. Highly-trained tennis player.
B. Untrained subject.
C. Highly-trained pitcher.

activity of the shoulder muscles slightly during the first half of forward swing. The disappearance of that activity was not observed in other cases. Therefore, the elbow was moved forward and the hand was left behind.

Probably the leg and trunk muscles worked to shift the body weight forward, resulting in coiling the link system of the body segments. Thereafter the muscles in the arm and shoulder contracted explosively to uncoil the link system.

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A THEORETICAL MODEL OF A PHYSIOLOGICALLY NATURAL GRIP FOR RACQUETS IN THE RACQUET SPORTS

by

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Abstract

The optimal hand position for an effective grip during the swing of a racquet is needed for a biomechanically efficient action. A physiologically sound grip should result in greater comfort, a more effective grip, better control of the racquet, and less chances of injuries. The design of a natural grip should thus be based on (1) the anatomy of the hand, (2) the kinematics of the wrist, and (3) an understanding of neuromuscular action.

Hand Structure: The anatomical nature of the human hand is capable of operating a racquet whereas the hand of the other primate is incapable of swinging a racquet as in a game situation. The way in which the human hand folds is different from other primates and this determines largely the nature of the physiological grip being advocated for racquets.

Kinematics of the Wrist: The wrist plays a very important role in racquet control and operation. The intercarpal joint, radiocarpal joint, and intercarpal joint participating in radial and ulnar deviation respectively, determine the proper direction of the racquet in racquet sports.

The Muscular Function of the Forearm: The muscular activities of the forearm are determined by a specific physical action. Maximum participation of a group of muscles in any specific action is more effective than having only a few muscles participate. A power grip is preferable in racquet sports such as tennis, racquetball and paddleball, because it brings into play more of the muscles needed to produce the desired action.

Introduction

There are two kinds of actions which can be performed by human hands, but not the hands of other primates: (1) the directional throwing action, and (2) holding a stick with directional operation such as poking or striking. These two actions are the basic survival techniques in the history of humankind. A great number of sports techniques today are essentially directly or indirectly related to the performance of these two actions. The ability to perform these two actions is based on the anatomical structure of human hand and the neuromuscular features of the arm. The special structure of the human hand and arm are the facilities which allow these actions to be performed.

What is a racquet game? A racquet game is when a biomechanical joint (human hand) connects to one end of an implement (racquet handle) and uses the other end of the implement (the racquet head) to hit a flying mass (the ball) in order to accomplish a certain performance. This question can be analyzed physically, biomechanically and physiologically:

(1) Physically: When a racquet hits a flying ball, it is simply a two-body collision. The results are determined by the physical nature of the two colliding bodies. The characteristics of the flying patterns of the ball after collision depend on the following factors: a) the masses of the ball and racquet, b) the velocities of the ball and the racquet, c) the contact angle of the ball to the face of the racquet, d) the resistance of the colliding surfaces, e) the elastic properties of the colliding bodies, f) the duration of the impact, and g) the direction and resistance of the air flow. By knowing the variables involved, the results can be learned and predicted by simple Newtonian mechanics and classical physics. It is unnecessary for anyone to understand the physics involved in order to play the game,

as the flying patterns of the ball can be learned and adjusted for from simple motor learning behaviors and patterned movement of the parts of the body, as in any other sport skill. Nevertheless, the understanding of physics will benefit anyone who wants to have a thorough knowledge of the game. However, it is important for sporting goods manufacturers and researchers to know the physics involved in the ball-racquet collision process in order to modify the parameters which are directly related to the physical nature of the game.

(2) Biomechanically: Using the human hand to operate and accelerate a racquet from a resting position to gain certain momentum and to manipulate the racquet to a certain position just before the contact of the ball, as in an ideal game situation, is a very important biomechanical problem. It basically involves the proper use of the human body and it's parts in mechanisms such as acceleration, momentum generation and control. In order to appreciate the biomechanics thoroughly, one should have the background knowledge about the anatomical structure of the body; theories of neuro-muscular action; the structure of the shoulder, elbow and the wrist joints; and the functions of the long flexors and extensors of the forearm. It is recommended that serious players, instructors, and coaches should have some understanding of the biomechanical nature of the game in order to reach a higher playing level and to teach the game more effectively themselves.

(3) Physiologically: The connection of the racquet to the human hand is a pure physiological problem. The human hand can be regarded as a physiological organ. It has specific anatomical structures. Flexion or extension of any part of the hand will be associated with specific

> muscular activities. When an object is held in the hand, it will affect the human body neurologically and muscularly. If the object to be held has a structure which fits the way the hand folds, one should have a feeling of "comfort" while gripping. What is comfort? It is simply a neurological reaction to a physical excitation. When one feels comfortable, he has less muscular stress.

The hand grip in racquet sports has long been regarded as one of the most important things, especially in tennis. Yet, it is the most controversial and least investigated in the long history of tennis. The tennis greats such as Pancho Gonzales and Butch Buchholz use a power hand grip for their forehand strokes, but many other great tennis players use and teach the conventional forehand grip with a spread forefinger. Holding a racquet in your hand is a very simple physiological action; why do people do it so differently? Since excellent tennis players use different hand grips, the simplest answer is to say that "these hand grips all work, it is a matter of personal preference". It is this kind of dogma which is the stumbling block of new developments in tennis. Even the good tennis players and coaches who would eventually benefit more than most through new understandings and new developments in the game are skeptical about new ideas and fail to ask the question "why?" themselves.

The basic problem of the hand grip controversy is caused by the non-ideal nature of the racquet grip itself, rather than the people who use it. This is a classical example of the learning behavior and the exceptional ability of the human body to perform and to adjust. The human body has great potential to learn and to perform with whatever tools it is provided. If one is provided with an undesirable tool, his performance will suffer due to the need of the body to compensate for the nonideal nature of the tool. In the case of the conventional tennis racquet grip, the non-ideal nature is low and the tolerance level of the body is very high, so through minor adjustment of the gripping fingers, players can still perform effectively. However, the performance level would be increased if a physiologically sound racquet grip is provided.

Gonzales and Buchholz hold their racquets with a grip of natural closure of their fingers simultaneously. They are using a hand grip which has the advantage of full participation of the groups of muscles performing the same function. Actually, they are using a better hand grip physiologically. But the power hand grip tends to force the straight racquet grip portion tilted toward the radial side of the hand due to the flexion of the index finger. This artificial deviation may cause off-center shots toward the lower side of the racquet face. To compensate for this, the players have to learn to contact the ball higher or their wrists and arms have to be lower than the most favorable physiological position to contact the ball. These factors would hinder them from performing to their best ability. The players who use the conventional forehand grip with a spread forefinger do not have a unified action of the flexors in their forearms. However, the spread-forefinger grip allows the racquet to be extended in the proper direction. To compensate the straight racquet grip with a spread-forefinger grip is a workable solution, if a firm hand grip is not required in the game. Problems arise when a tighter hand grip is needed such as during the ball contact in a stroke. The index finger tends to flex together with other fingers if no special attention is paid to prevent it from flexing. Thus, the artificial deviation of the racquet toward the radial side of the hand may be generated and off-center shots toward the lower side of the racquet may result. It is a common experience, that in a game, a player often checks his hand grip at the beginning of a play, but that does not ensure him of a proper hand grip during play.

It is the purpose of this paper to provide a model for a physiologically sound racquet grip which would allow the players to perform to their best ability and reduce the chances of arm injuries.

Theoretical Background

The design of the ideal physiological hand grip is based on the physiological functions and the anatomical structures of the hand and the wrist.

A. The anatomical nature and physiological function of the hand.

The physiological nature of the hand has never been fully analyzed. No effort is made here to make a complete analysis of the functions of the human hand. Only the physiological function which relates to racquet sports will be discussed. As mentioned before, the human hand is a self-adjustable biomechanical joint. One of it's main physiological functions is neuro-muscular controlled gripping. There are two kinds of hand grips which the human hand can perform: a) the precision hand grip, and b) the power hand grip. The precision hand grip involves flexion and extension of the phalanges at the distal end of the digits. It usually requires the manipulation and operation of the fingers. The power hand grip is formed when an implement is heavy or when the speed of performing a specific action is fast. The involvement of the phalanges will progress from the distal to the proximal ends of the digits, until finally, all the phalanges are flexed to their utmost at the metacarpo-phalangeal joints such as in a clenched fist. The long flexors and extensors will be predominantly activated either actively or passively.

The most straight-forward approach to studying the nature of the hand grip is to study the ways the human hand folds. One way to learn how the human hand folds is to investigate the creases on the surface of the palm. The coarse and more conspicuous lines on the palm are flexure lines. These lines have long been used by palmists to read the characteristics of a person and to tell fortunes.

Here, we are interested in these lines solely as anatomical structures having definite relations to the physiological function of the hand. The flexure lines, no matter where they are present on the surface of the body, are simply the registration of the mobility of the bony tissues underneath. Usually these lines do not mark the exact location of the bony joints because there exists various thickness of intervening tissues.

There are three flexure lines which mark the closing movements of the metacarpal-phalangeal joints in forming the physiological hand grip.

(1) The distal transverse palm crease D (as in Figure 1a).

The distal transverse palm crease, D, starts upon the ulnar border and runs toward the radial side of the palm. This line covers the metacarpal-phalangeal joints of the middle, ring, and little fingers and ends at the interdigital clift between the index finger and the middle finger. This line is formed due to constant folding of these three fingers. The distal transverse palm crease that does not cover the base of the index finger is a typical human condition. This indicates that the index finger has freedom to perform independent functions. For other primates (monkey, gorilla, chimpanzee), their distal palm crease will run all across the palm surface and cover the bases of all four fingers.

(2) The proximal transverse palm crease, P.

The proximal transverse palm crease starts upon the radial side of the hand between the thumb and the index finger. It's origin is usually blended with that of the radial longitudinal crease, R. It disassociates with the radial longitudinal crease after passing the base of the metacarpal-phalangeal joint of the index finger and runs toward the ulnar side of the hand. It usually disappears before it reaches the hypothenar eminence. This line is created through constant folding between the thumb and the index finger.

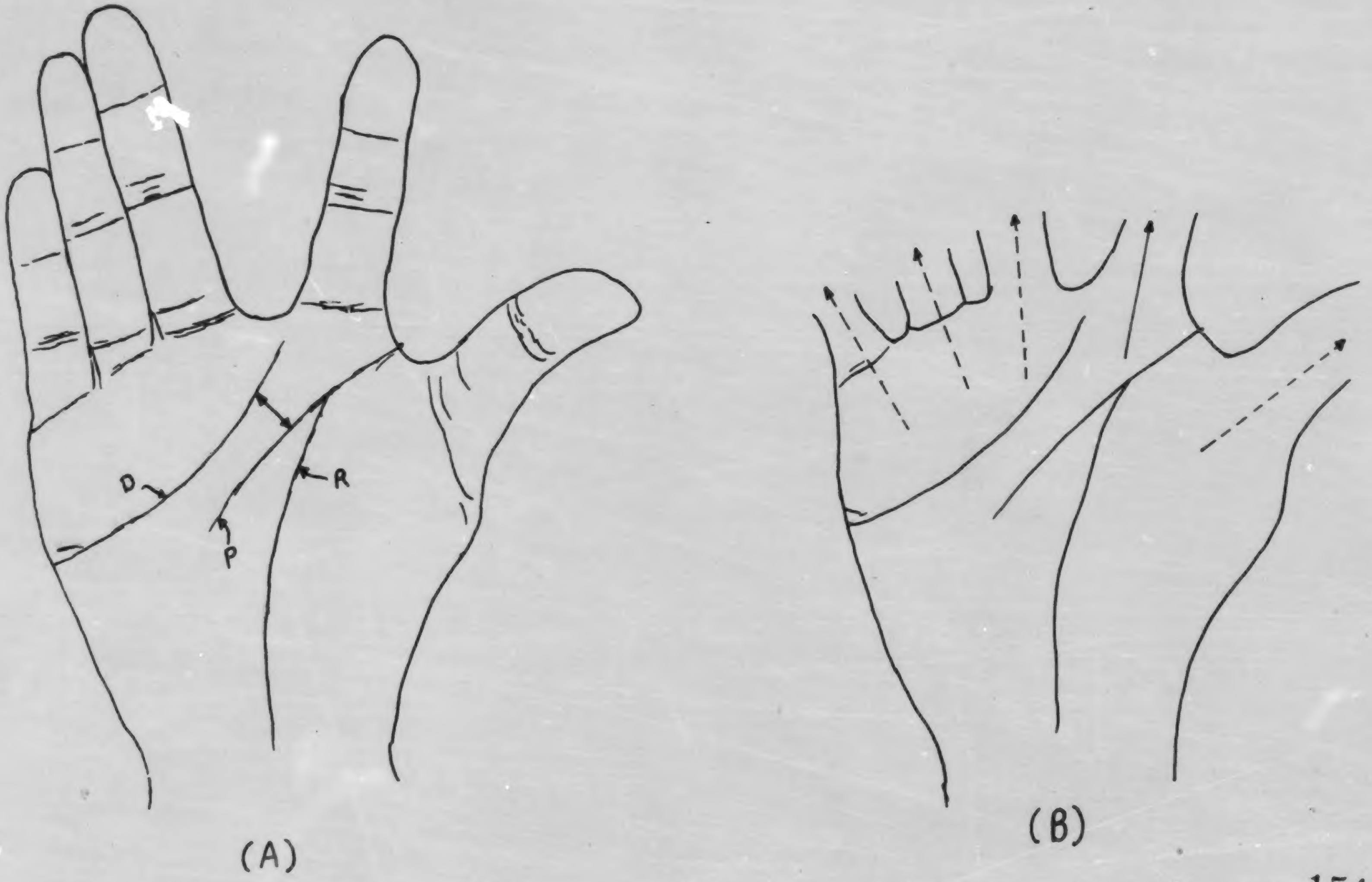

FIGURE 1

(A) The non-linear nature of human hand grip.

(B) The solid line shows the proper direction of the racquet in the human hand.

(3) The radial longitudinal palm crease, R.

The radial longitudinal palm crease, R, begins in common with the proximal transverse palm crease from the radial border. It encircles the thenar eminence and the metacarpo-carpal joint of the thumb. This line is created through constant opposing action of folding the metacarpo-carpal joint of the thumb.

These three flexure lines define three functional units of the hand. The thumb has a double role to play. As can be seen from a clenched fist, the distal phalanx of the thumb opposes the direction of the middle, ring and little fingers, while the proximal phalanx of the thumb opposes the direction of the index finger. When all fingers are closed simultaneously, two separate grips are formed. One grip is between the thumb and index finger, the other grip is between the thumb and the middle, ring and little fingers.

In racquet sports, the grips formed involve the flexion of the proximal phalanges of all the fingers. These grips are power grips in nature. When a full-handed grip or a power grip is formed, there is a distance (Figure 1A) that separates the folding between the thumb and the index finger and the folding between the thumb and the middle, ring, and little finger. The distance between the distal transverse palm crease, D, and the proximal transverse palm crease, P, defines the off-set nature of the full-handed grip. This is the reason why the conventional racquet with a straight racquet grip does not fit into the structure of a human hand.

B. The kinematics of the wrist and it's relation to racquet sports.

The kinematics of the wrist has been well studied by Youm, et al., (1). The parameters which play very important roles in racquet sports are flexion-extension, and radial-ulnar deviations. Flexion-extension of the wrist is the primary mechanism for preparation and acceleration of the racquet along with the horizontal direction. Radial-ulnar deviations of the wrist are the primary mechanisms for adjusting the racquet to the proper position to contact the ball along the vertical direction. Radial-ulnar deviation is also the determining factor for the proper direction of the racquet in a player's hand. In the previous discussion, it was stated that due to the off-set nature of the human hand grip, a power grip may force the conventional straight racquet to deviate from it's proper direction. What is the proper direction? Is there really a proper direction of the racquet in the hand of a player? The answers to these questions will become more apparent if we make up a fictitious story and ask a hypothetical question.

There was once a professional tennis player who, in an accident, lost all the fingers of his playing hand. He loved tennis so much that he tried everything humanly possible to keep playing the game. Fortunately, a magic glue was invented. The magic glue had the properties that it could glue the racquet to the player's hand and could also be washed off easily. The hypothetical question now is: Where will he glue the racquet to his hand? There are numerous directions in which the racquet could be glued on, as shown by the arrows in Figure 1B, but there is only one position, theoretically, that is best for him physiologically to play the game. The two extreme cases were the racquet being glued in the directions of the thumb or the little finger. In both cases, the player has to learn to use his body to compensate for the improper directions. Since he is a good tennis player, he may still be able to play an average game, if he practices enough. The point is that there is only one direction which is best for his wrist function, and his body does not have to learn to make any compensation. The ideal direction of the racquet for an over-all racquet game is shown by the solid arrow in Figure 1B. It is in the direction of the index finger, when the index finger is fully extended. An angle is formed of approximately $12^{0} \pm 2^{0}$ relative to the longitudinal axis of the forearm. The reason why this is the most favorable physiological position can be explained by the structure and function of the wrist, shown in Figure 2. For clarity, only part of the carpal bones were traced. The importance of the wrist function here is the rotational sliding motion of the radio-carpal joint during ulnar deviation, as shown in Figure 2B. In radial deviation, the radio-carpal joint does not move, only carpal-carpal joints are involved. The participation of the radio-carpal joint makes the wrist lower the racquet more effectively. As a result, the wrist can usually deviate approximately $12^{0} \pm 2^{0}$ more to the ulnar side than to the radial side of the hand. Placing the racquet in the direction of the extended finger will compensate for the physiologically unfavorable nature of the radial deviation and put the racquet in the optimal range of wrist function.

C. Neuromuscular functions related to the hand grip.

No attempt is made to cover any part of the theory of neuro-muscular action. Since the nature of a racquet grip is closely related to the neuro-muscular nature of the hand, there should be at least a brief discussion of the nerve systems which affect the flexors in forming the human hand grip.

The median nerve system which originates from the 6th, 7th and 8th cervical roots, as well as from the 1st dorsal is the most important nerve related to human hand function. The function of the median nerve is a mixed one, subserving many forms of sensitivity and supplying motor neuraxons to the pronator-flexor group of muscles. It supplies epicritic sensitivity and motor function of the thumb, index and middle fingers and the corresponding portion of the palm of the hand. The median nerve system plays the most important role in racquet control and operation.

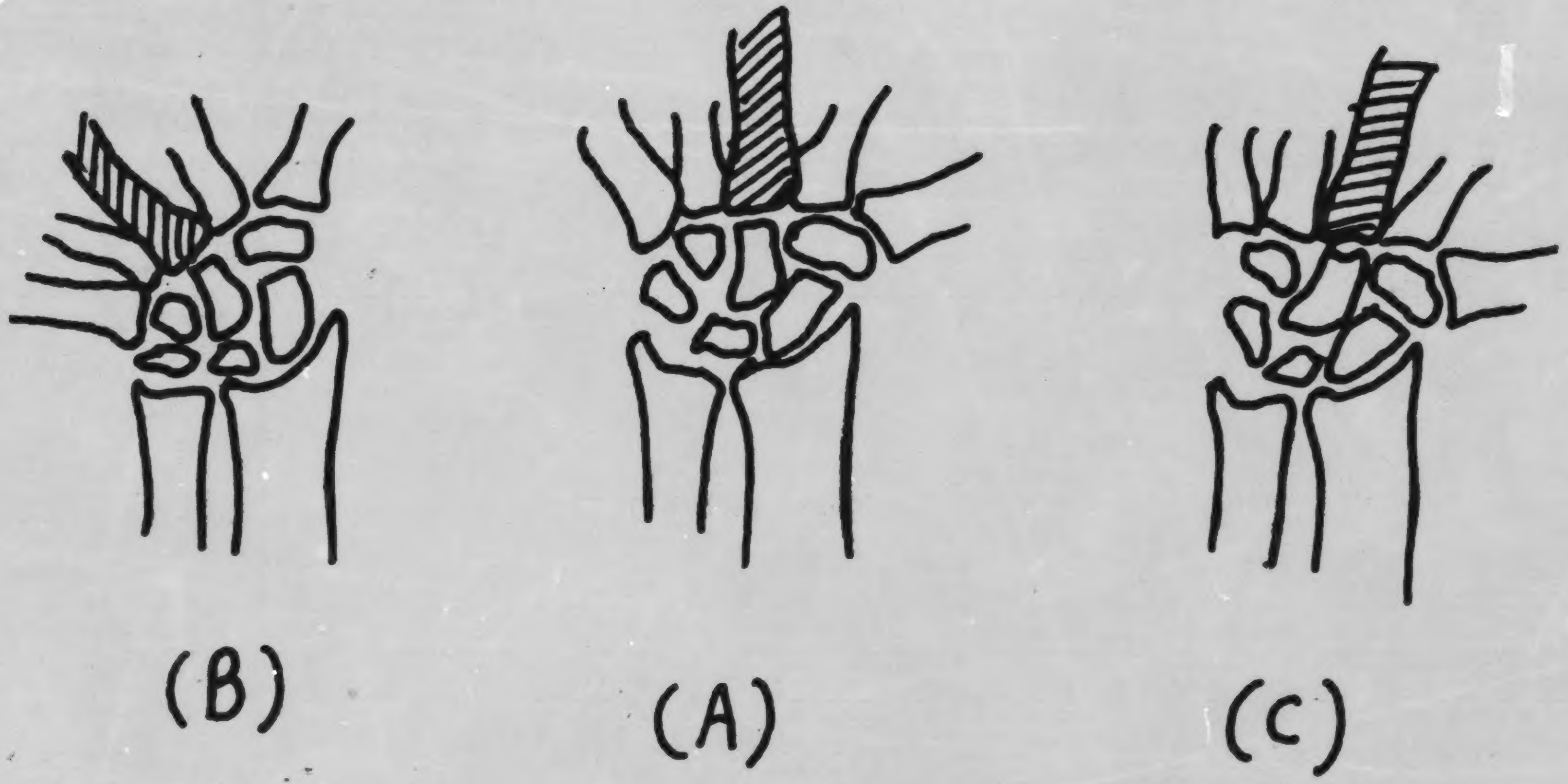

FIGURE 2

(A) Partial tracing of the carpal bones of human hand at neutral position.

(B) The rotational sliding motion of the radio-carpal joint during ulnar deviation.

(C) Positions of partial carpal bones during radial deviation.

The ulnar nerve system provides sensory nerve and motor fibers of the flexor muscles for the ulnar side of the hand. In the palm, there is a deep branch extending toward the radial side of the hand and entering the upper portion of the thenar eminence. It is the overlapping of the median and ulnar nerves in this area that provides the thenar eminence with the synergistic action for hand operation. Since the thenar eminence is responsible for the synergistic action of hand operation, it is important that the racquet grip should contact the thenar muscle as much as possible.

Theoretical Model

From the previous discussion, the model proposed has to satisfy the following conditions:

1. The grip has to be non-linear in nature.
2. There should be a distance to compensate for the closing movements between the thumb and the index finger, and between the thumb and the middle, ring and little finger.
3. The grip can be used in a power grip without causing a deviation in the direction of the racquet.
4. This grip has to provide maximum contact surface to the thenar muscles pad in either forehand or backhand play.

Based on the conditions, the theoretical model was provided. It is the Model A as shown in Figure 3. Model B (Figure 3) is given for comparison and discussion. Both models meet the requirement of non-linear nature of the human hand grip. Model A provides the area A (Figure 3) for the index finger, Model B provides a declined surface which enhances the involvement of the ulnar side of the hand, but reduces the contact of the thenar eminence. Both models can be used with a power grip. Only Model A can provide proper contact surface for either forehand or backhand play. Model B is hard on backhand play and is especially detrimental in

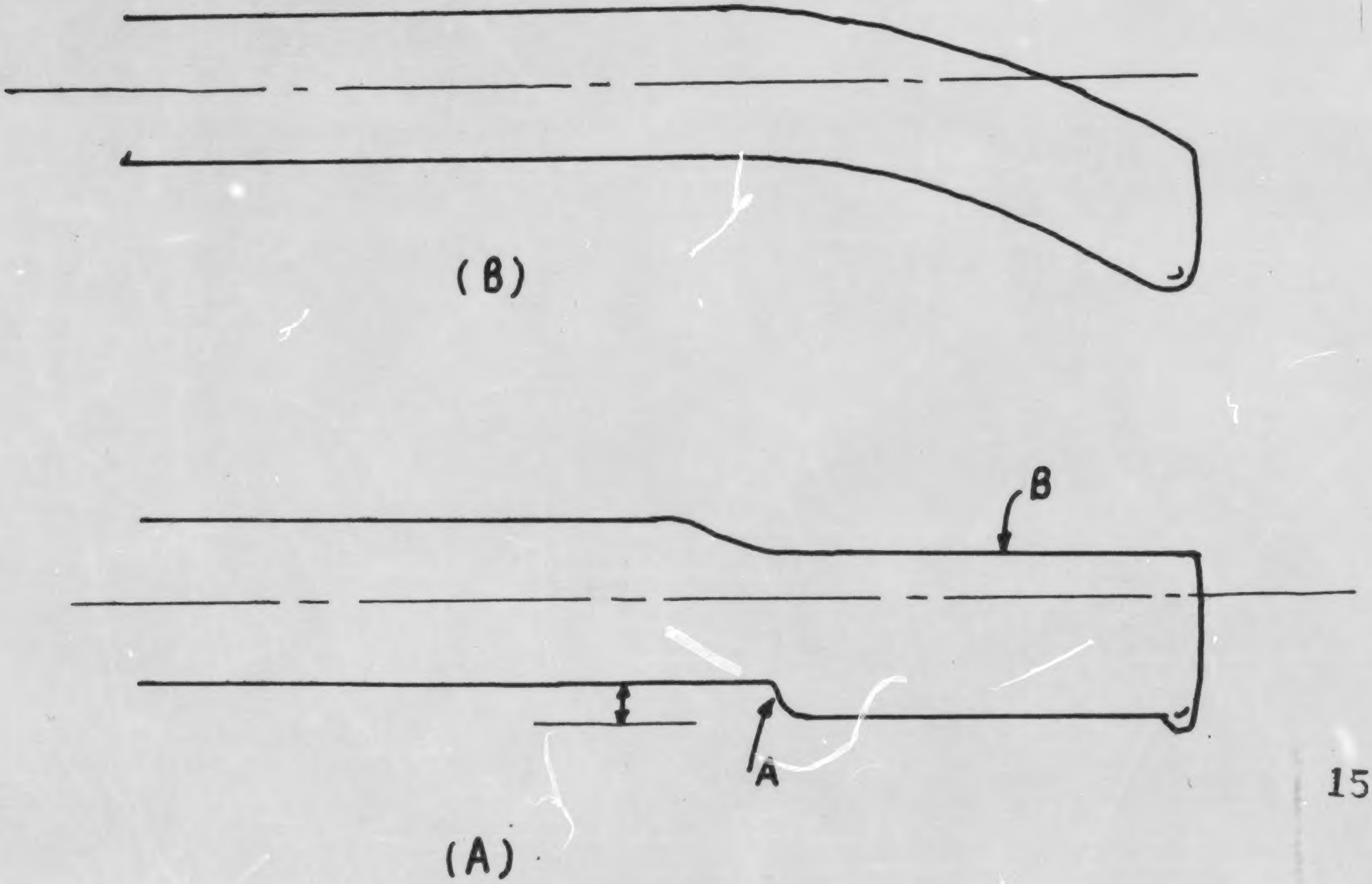

FIGURE 3

(A) The natural physiological grip suitable for directional and leveling operations.

(B) Non-linear grip not suitable for directional and leveling operations.

volleying or for any stroke which the racquet head needs to be high to begin with. The declined surface on the upper part of grip as in Model B is the basic weakness of this model. It works against the wrist structure and makes the difficult radial deviation even harder. Therefore, Model B has to be excluded from racquet sports, but it can be useful in a pulling or pushing action where no leveling action or directional operation is involved.

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MOTOR LEARNING
AND
TEACHING STRATEGIES

DEVELOPMENT AND UTILIZATION OF AN OBSERVATIONAL TOOL FOR ASSESSING ATHLETIC PERFORMANCE IN RACQUET SPORTS

by

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Abstract

The purposes of this presentation are: (1) to present an observational tool that can be used by coaches and teachers, specifically racket sport coaches, for collecting behavioral data on athletes during practice and the actual competitive events; (2) to present how this tool can be used to modify athletes' behaviors during practices and the competitive events; (3) to present how this tool can also be utilized as an effective device for self- and/or peer evaluations and how it can be used in conjunction with delayed feedback through the use of VTR, and (4) to present the effects of how it can also be effectively used to alter an individual's performance rate when combined with various reinforcement schedules.

Within this presentation, the speaker will relate to how data collected through the use of observational techniques can render important information to athletes and coaches, and how based upon the data collected, goal setting can be instated in order to determine if the athlete's behavior can be altered effectively during practices, and consequently during the competitive event. A recommended rating scale will be presented, categories defined, and sample situations presented through video tape playback will be shown to give the audience practice in using the tool. Findings from research studies using this tool will also be presented and discussed.

Data collected through the use of various observational techniques can render important information to coaches, athletes, and teachers. Behavioral data collected during practice sessions and during the actual competitive events can be used to modify athletes' behaviors during practices and competition. Based upon the data collected, goal setting and various reinforcement schedules can be instated in order to determine the frequency and effectiveness of the behavior changes. Observational tools can also be utilized as an effective device for peer evaluations and for increasing self-awareness in conjunction with delayed feedback through the use of VTR (video tape replay). Self-awareness is a very important component that must be developed within the racket sports competitor, partly because of the nature of the sport which requires the athlete having to react quickly to each situation, and partly because of the restrictiveness of the rules which do not permit the coach to have any or little communication with the player until the completion of the match.

Meaningful, as well as immediate evaluation and feedback, is an important aspect in the total learning process of the athlete. The factors that contribute to the performace rate and successfulness of an individual athlete should be defined, in behavioral terms, evaluated during performance situations, and information relayed back to the athlete.

The research in Badminton, both teaching and competitive, has been scarce. Most of the writings and studies have centered around the effectiveness of various teaching methodologies, or toward studying isolated skills or stroke development. Intelligence and skill in relation to success in singles competition in badminton and tennis was researched by Thorpe (4). The results revealed a significant F ratio between skill level and success in competition for both sports, and a nonsignificant F ratio for intelligence and success.

The effect of timing of verbal comments in relation to the replay of videotape on the ability of highly skilled intercollegiate badminton players was researched by Barker (1). Two skills were selected for analysis; the serve and the return of serve. The results of the analysis revealed that there was no significant difference in serve and return of serve effectiveness due to any of the videotape interventions. There was, however, a significant difference of the skills between ability levels as the highest ability players were the most effective in executing serving and returning serves.

Success in competition can be related to many factors. Certainly, one item that needs to be explored is the effectiveness of the shots, both placement and consistency, during practice and during competition. By instructing observers to chart performance, players can receive immediate feedback as to the effectiveness of their shot choices and mechanical execution of the strokes. Based upon the percentages collected, individual goal setting can be established as a means of increasing effective playing percentages. By training peers as evaluators, along with the teacher and coach, the number of players that can be charted substantially increases. If the number of persons trained to use the scale is limited, the amount of information and the number of players that can receive feedback, is also limited and restricted. Peers can become reliable observers by carefully defining the categories and through repetitive practice sessions.

The rating scale developed by Phillips (3) has been utilized in conjunction with badminton instructional classes and with intercollegiate badminton players. In order to field test the rating scale and to establish the validity and reliability of the categories, a pilot project was conducted. The data obtained from this project were used in the establishment and definition of the rating scale categories. The technique used to collect the data was continuous event recording

Reliability of the tool was determined by totalling the number of agreements and disagreements in each category and inserting the sums of all categories into the following formula (Hall, p. 18) (2)

$$\frac{\text{Agreements}}{\text{Agreements + Disagreements}} \quad X \quad 100$$

The information obtained from this type of an instrument renders tangible evidence of performance during actual game play. It produces an accurate performance measurement rather than a 'hit and miss' evaluative summary from memory of the events of each game.

The rating scale categories have been devised to record and assess singles and doubles game play competency. Data obtained from this evaluation can be converted to game play percentages for effective serves, return of serves, shots during the rallies, and faults.

The uses for this type of a device are numerous. Besides charting performance and feeding back information to players, the date rendered from this type of an instrument could be analyzed through and between comparisons of game playing performance and competency by ability levels. By rank ordering the players into ability groups of flights, the investigator could analyze the data by comparing the level-group mean percentages for each category and the number of faults committed during game play. The data could also be subjected to comparisons of effective percentages and differences during practice sessions and actual competition. A possibility that also needs to be explored is whether charting a peer can be transferred to the actual playing court and increase a player's performance competency during game play.

Both the multi-element and multi-baseline designs are appropriate for studies that can be conducted in the coaching setting, utilizing a rating scale as a means for collecting data. Various reinforcement schedules as well as the effects of positive and corrective feedback needs further study in the coaching field. Collecting data through this type of a rating device is a beginning attempt at studying the effectiveness of certain, selected behaviors during practice compared to the consistency of the same behaviors during the competitive events.

This particular rating instrument was developed for badminton, but is adaptable and appropriate for most racket sports. The serve and return were determined to be separate categories from the shots taken during the rallies because of their importance during the game. In badminton play, the serve is the only means of accumulating points and the return of serve shot choice determines offensive or defensive court positioning. Because badminton is considered to be an open-ended sport, the possibilities of shot choices, and placement of each shot appears to be linked with the ability level of the performer and with the confidence of the player to execute certain types of shots. The performer is required to perform basic skills, learned and practiced in a somewhat closed and convergent situation, which transfers to a divergent application during game play. Therefore, the category shot choice during the rallies can be adapted and modified to the experience and ability level of each performer.

Tangible evidence of game play performance is helpful to all performers. The information obtained from a rating scale offers permanent proof, in the form of a written record, of how the player performed. The information also provides the researcher-coach the opportunity to study the players behaviors under a variety of research techniques and competitive conditions.

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A COMPARISON OF PERFORMANCE CHANGES IN NOVICE TENNIS PLAYERS WHEN LEARNING EITHER A ONE-HANDED OR TWO-HANDED TENNIS BACKHAND DRIVE

by

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Abstract

The purpose of this investigation was to compare the differences in skill acquisition between two groups of novice tennis players when learning either the one-handed or two-handed backhand tennis stroke. It was anticipated that such a study could contribute to the body of knowledge concerned with teaching strategies in the game of tennis.

One hundred twenty-one men and women subjects enrolled in beginning physical education tennis classes at the University of Illinois participated in the study. Subjects were taught either the one-handed or two-handed method of performing the tennis backhand drive. Each subject was pre-tested at the beginning of the eight-week instructional session and post-tested at the end of the session. The results indicated that there was significant improvement for each stroke type at the end of the course, but that no significant difference existed between those who learned the one-handed backhand drive and those who learned the two-handed backhand.

Human motion is based on fundamental principles which comprise the intricate movement patterns of a motor skill. Occasionally, several motor skills, where the human motion is different, can be utilized by an individual to achieve identical outcomes. Prime examples of two such skills that were performed differently, yet result in similar outcomes, are the tennis one-handed and two-handed backhand drives.

Historically, the one-handed backhand has been used by competitors since the origination of tennis in the 1870's (Budge, 1945). In contrast, the two-handed backhand ground stroke was virtually unknown until the 1930's when Vivian McGrath became the world's first top-ranking player to compete with it (Metzler, 1969). Only a few of the better players used the two-handed backhand after that, but it has recently become popular since it is used by several world class performers (Segura & Heldman, 1975). These performers preferring the two-handed stroke perhaps began using it when they either did not have enough strength or confidence to control the motion of the tennis racquet when utilizing the one-handed backhand. If this reasoning is valid, then several controversial questions are apparent about the two-handed backhand. For example, will using the two-handed backhand actually solve problems associated with lack of strength or a player's lack of confidence? More specifically, would using a different racquet which has less mass or less length (one with a lower moment of inertia) than the player's original racquet compensate for any lack of strength and permit that person to use a one-handed backhand instead of a two-handed backhand? Finally, are there any significant differences in a beginner's skill acquisition between the one-handed and the two-handed backhand drives?

Scientific literature exists analyzing and describing the tennis one-handed backhand drive, but few studies have been conducted regarding the two-handed backhand. Reinhardt (1976) compared the differences in skill acquisition between two groups of subjects who learned either the one-handed or two-handed backhand drive. No differences in performance were determined between the groups but this was attributed to the small sample size studied (16 subjects per group). The results suggested that significant improvement occurred in performance for both groups but no differences existed in skill acquisition between groups.

Until recently, the two-handed backhand has been viewed as an affectation by tennis teachers and professionals who use traditional techniques (Helfrich, 1976). This may partially explain the lack of scientific study and available literature on the two-handed ground stroke. Helfrich (1976) observed that the two-handed backhand is not usually taught because most instructors do not understand the mechanical principles involved in that technique. Groppel (1978) conducted a kinematic analysis of the one-handed and two-handed backhand drives of highly skilled female competitors. He suggested,

> "... that the two-handed backhand could be the preferred stroke when hitting a tennis ball while able to position one's body comfortably with respect to the ball." (p. 90)

Although more study is necessary, it may be concluded that the literature reveals a positive trend toward teaching students the two-handed backhand as well as, or possibly instead of, the one-handed backhand drive. Therefore, it was the purpose of this investigation to compare the differences in backhand drive skill acquisition between two groups of novice tennis players who were instructed in either the one-handed or two-handed ground stroke. The information gained from such an analysis would hopefully assist the instructor and/or coach in selecting the appropriate stroke type and in teaching both movements.

Procedures

Subjects for this study consisted of male (N=45) and female (N=76) students enrolled in elective beginning tennis classes at the University of Illinois at Urbana-Champaign. The 121 subjects were enrolled in 10 different co-educational beginning level tennis classes. Students in five of the classes (N=56) were taught a one-handed backhand drive. Students in the other five classes (N=65) were taught a two-handed backhand.

Teachers involved in the study were given intensive instruction in either the one-handed or two-handed backhand tennis stroke. In an effort to standardize the instruction of the classes and teaching of the students, an eight-week lesson plan was used by the instructors. Also, a video-tape recording of both strokes was made for the initial teaching period. Subjects viewed the video tape and practiced the appointed stroke simultaneously with the taped lesson.

The eight-week lesson plan used by the instructors was flexible concerning all aspects of beginning tennis except for the backhand drive practice. Each instructional session specifically designated the drills to be used and the time allotment for backhand practice. All classes were held outside on laykold tennis courts during good weather and in a gymnasium during inclement weather. Classes met twice weekly, one and one-half hours per session. Students were also requested to limit their practice to under five hours per week outside of class and, when hitting a ball on the backhand side of their body, to practice only the backhand stroke they had been taught in class.

All subjects were pre-tested with a modified Broer-Miller Backhand Drive Test before any instruction was administered. The modification consisted of using a ball machine instead of a self-drop method and the elimination of the rope above the net (Broer & Miller, 1950).

A "Little Prince" ball machine was positioned on the opposite side of the net from the subject. It was set on "low" velocity and timed to project balls every five seconds. Each subject was given five practice contacts with the ball and ten actual trials were recorded on a score sheet. The highest possible score one could attain was eighty. At the termination of the eight-week instructional session, the modified Broer-Miller Backhand Drive Test was again used as a post-test. The conditions of the post-test were identical to those of the pre-test.

Results

Frequency distribution and accompanying percentages of the pre-test scores are shown in Table 1. The authors arbitrarily grouped the raw scores into categories of low (0-28), medium (30-50) and high (52-80). Using these categories, 51.7% (N=29) of the subjects who were going to be taught the one-handed backhand were determined to have low scores on the pre-test, 32.1% (N=18) had medium scores on the pre-test, and 16.1% (N=9) had high scores on the pre-test of backhand ability. Of the subjects who were going to be taught the two-handed backhand, 63.1% (N=41) had low scores, 33.6% (N=22) had medium scores, and 3.0% (N=2) had high scores on the pre-test of backhand ability.

Table 2 depicts the post-test scores for the subjects. Using the same arbitrary grouping as for the pre-test scores, 21.6% (N=12) who were taught the one-handed backhand were considered to have low scores on the post-test, 46.5% (N=26) had medium scores on the post-test, and 32.1% (N=18) had high scores on the post-test of backhand ability. Of the subjects who were taught the two-handed backhand, 15.3% (N=10) had low scores, 54.1% (N=35) had medium scores, and 30.7% (N=20) had high scores on the post-test of backhand ability.

Table 3 shows the means, standard deviations, and calculated t-tests of both the pre-test and post-test scores. As would be expected, both groups improved significantly between their respective pre-test and post-test scores. Thus, all subjects improved significantly on the measure of backhand performance from the pre-test to post-test dates without regard to whether they were taught the one-handed or two-handed ground stroke.

TABLE 1

Frequency Distribution and Accompanying Percentages for the Pre-test Scores

Pre-test Score	One-Handed Backhand N	% of One-Handed Backhands	Two-Handed Backhand N	% of Two-Handed Backhands
0	2	3.6	3	4.6
2	4	7.1	0	0.0
4	0	0.0	3	4.6
6	1	1.8	1	1.5
8	2	3.6	1	1.5
10	1	1.8	3	4.6
12	4	7.1	4	6.2
14	0	0.0	5	7.7
16	3	5.3	2	3.1
18	1	1.8	2	3.1
20	3	5.3	2	3.1
22	2	3.6	2	3.1
24	3	5.3	6	9.2
26	2	3.6	5	7.7
28	1	1.8	2	3.1
30	2	3.6	1	1.5
32	1	1.8	3	4.6
34	2	3.6	1	1.5
36	3	5.3	3	4.6
38	4	7.1	3	4.6
40	1	1.8	4	6.2
42	1	1.8	3	4.6
44	1	1.8	1	1.5
46	3	5.3	1	1.5
48	0	0.0	1	1.5
50	0	0.0	1	1.5
52	4	7.1	0	0.0
54	2	3.6	1	1.5
56	1	1.8	0	0.0
58	1	1.8	0	0.0
60	0	0.0	0	0.0
62	1	1.8	0	0.0
64	0	0.0	1	1.5
TOTAL	56	99.9	65	99.7

TABLE 2

Frequency Distribution and Accompanying Percentages for the Post-test Scores

Post-test Score	One-Handed Backhand N	% of One-Handed Backhands	Two-Handed Backhand N	% of Two-Handed Backhards
6	1	1.8	0	0.0
8	0	0.0	0	0.0
10	1	1.8	0	0.0
12	3	5.4	1	1.5
14	0	0.0	1	1.5
16	1	1.8	1	1.5
18	1	1.8	0	0.0
20	0	0.0	2	3.1
22	3	5.4	0	0.0
24	0	0.0	2	3.1
26	0	0.0	1	1.5
28	2	3.6	2	3.1
30	1	1.8	2	3.1
32	0	0.0	2	3.1
34	1	1.8	2	3.1
36	0	0.0	4	6.2
38	4	7.1	3	4.6
40	3	5.4	5	7.7
42	4	7.1	4	6.2
44	5	8.9	2	3.1
46	3	5.4	4	6.2
48	2	3.6	4	6.2
50	3	5.4	3	4.6
52	2	3.6	6	9.2
54	4	7.1	1	1.5
56	4	7.1	2	3.1
58	1	1.8	5	7.7
60	4	7.1	2	3.1
62	1	1.8	1	1.5
64	2	3.6	2	3.1
66	0	0.0	1	1.5
TOTAL	56	100.2	65	100.1

TABLE 3

Means and Standard Deviations for the Pre-Test and Post-test of Backhand Ability

	ONE-HANDED STROKE			TWO-HANDED STROKE		
	$\bar{X}$.	S.D.	t	$\bar{X}$.	S.D.	t
Pre-Test	28.3	17.3	6.04*	25.1	14.5	10.1*
Post-Test	41.9	15.3		42.9	13.0	

* $t_{.05(119)} = 1.98$

To test whether there was a difference in performances between the one-handed backhands and two-handed backhand groups, a t-test was calculated. This statistic, calculated between the mean of the pre-test scores for the one-handed group and the two-handed group, equalled 1.12. That was not significant and therefore, indicated no difference between the two groups prior to instruction. The t-test calculated between the mean of the post-test scores for the two groups equalled 0.4 and was also not significant indicating no difference between the two groups following the instructional period. Thus, after eight weeks of instruction, no difference in backhand performance was demonstrated between the beginning level tennis players who were taught the one-handed backhand and those who were taught the two-handed backhand.

Discussion

The implications of this study concern teaching methodology for tennis instructors and coaches. Data from this study seem to support that of Reinhardt's (1976) investigation suggesting that both methods of performing a backhand result in a comparable improvement when taught to novice tennis players. It is of value to note that with the increased sample size and the combination of male and female subjects in this study, the results of both studies were analogous.

Thus, no significant differences were determined between performance scores for the two samples of backhand drives.

Although no significant differences were calculated between improvement for the two-stroke technique, one should not dismiss the fact that this study encompassed only an eight-week instructional session involving two classes per week. No actual controls were possible to monitor the amount of practice of the students, but they were requested to limit practice time to under five hours per week. Therefore, it may still be feasible that one stroke is more mechanically effective than it's counterpart, but, within the limitations of this investigation, there seems to be no differences in improvement of performance. The practitioner should be aware that the results of this study are, in no way, completely conclusive.

Obviously, instructors should be aware of the basic principles involved in both methods of performing a backhand drive (Groppel & Ward, 1979; Helfrich, 1977). With the increased awareness of successful amateur and professional tennis players using the two-handed backhand, more and more beginning level players are asking to be introduced to the two-handed method as well as the one-handed stroke (Stolle, 1977). Even intermediate and highly-skilled players who were previously taught the traditional one-handed backhand have also been observed to experiment with the two-handed stroke. The data from this study suggest that tennis students should perhaps be allowed to choose the backhand stroke type which would be most appropriate for him or her. Caution is necessary, however, when the student may have physical difficulty (due to strength, coordination, etc.) in effectively using a one-handed backhand (Groppel, 1976).

As the demand arises, teachers and coaches will be expected to comply. The two-handed backhand is no longer a fad but a special skill which may well be learned by teachers and coaches so that a proper judgment can be made on the appropriateness of the stroke for individual players.

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THE JAMES-LOWELL RACQUETBALL TEST: A SKILLS AND ABILITY TEST FOR USE IN INSTRUCTIONAL RACQUETBALL

by

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Abstract

With the recent rapid growth in popularity of racquetball, many colleges are now adding the sport to their physical education curriculum. Very few tests exist at present which are able to systematically and reliably classify students' racquetball abilities so that instructional programs can focus on individual needs. Instructors of coeducational racquetball service classes are faced with the need for an effective skills and ability test to use in evaluating and grouping students for maximum benefit.

The James-Lowell Racquetball Test, Form A and Form B, has been designed to classify students according to ability and knowledge levels as beginning, intermediate, and advanced for college coeducational activity classes. Form A tests specific racquetball skills, while Form B measures students' knowledge about the sport. Easy to score and administer, the test can be given in one class period. Validity is currently being measured.

In addition to being useful at the start of classes, the test can be used again for self-evaluation during and at the end of the instructional quarter or semester. It is a tool which should greatly facilitate planning for racquetball instruction in college coeducational activity classes.

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THE JAMES-LOWELL RACQUETBALL TEST

FORM A: ABILITY

Equipment Needed:

1. Regulation, four wall racquetball court
2. 2" masking tape
3. Ten regulation racquetballs with container for extra balls
4. Score sheets and pencils
5. A stop watch

The James-Lowell Racquetball Test, Form A, has been designed to classify coeducational racquetball service classes into beginning, intermediate, or advanced ability levels. It consists of a thirty second front wall rally in which the subject may use any grip, stroke and stance to strike the ball in such a way that it rebounds off the front wall. The subject's score will be the total number of hits that strike the front wall on or below a two-inch line, five feet above the floor and which are hit while the subject is in a ten foot by twelve foot rectangle marked on the court surface behind the short service line. The subject will have three thirty-second trials.

Subject directions. Stand within the rectangle (indicate the rectangle behind the short line) with three balls in your non-racquet hand. On the signal "Ready-Begin" strike the ball so that it hits the front wall on or below the five foot line (indicate line on front wall). As the ball rebounds, attempt to rally it against the front wall and on or below the marked line. After starting the ball you may hit it as it comes off the front or side wall either before it bounces or after any number of bounces. Only those shots hit while at least one foot is within the rectangle, which hit on or below the five foot line and which contacts the front wall immediately after contact with the racquet will be scored. You may go anywhere on the court to retrieve balls but any hits made from outside the rectangle or which strike the side wall, floor, or ceiling before hitting the front wall will not count. Try to keep the ball going but if you lose control of a ball or miss it, do not attempt to recover it. Start a new ball by striking it as you did the first one. Your first trial is over when I say "stop" at the end of thirty seconds. Your score is the sum of the last three trials.

Scoring. The number of hits against the front wall on or below the five foot line, while staying inside the ten by twelve foot rectangle in thirty seconds is the score for each trial. The total of the last two trials will be the subject's score.

THE JAMES-LOWELL RACQUETBALL TEST

FORM B: KNOWLEDGE

The James-Lowell Racquetball Test, Form B, has been designed to classify coeducational racquetball service classes into beginning, intermediate or advanced knowledge levels. It consists of fifteen multiple choice items which can be administered in that time period when the subject is not on the court for the James-Lowell Racquetball Test, Form A: Ability.

Directions:

Each question in this test is followed by four suggested answers. Read each question and then decide which one of the four suggested answers is best. Find the row of boxes on your answer sheet which has the same number as the question. In this row, mark the box having the same letter as the answer you have chosen.

EXAMPLE

Chicago is a (A) state; (B) city; (C) country; (D) continent.

On the answer sheet mark your answer in the following manner:

(A) (B) (C) (D)

The correct answer to this question is lettered B, so box B is marked.

Go on to the next page, begin the test. Please mark your answers on the answer sheet that is provided. Please DO NOT mark on the test. As soon as you have finished return the test and answer sheet to the proper box.

THE JAMES-LOWELL RACQUETBALL TEST

FORM B: KNOWLEDGE

1. The man who is usually given credit for the development of a game which has become known as racquetball is:

   (A) Joe Sobeck; (B) Earl Riskey; (C) Bud Muehleison; (D) John Campbell.

2. The game of racquetball may be played by:

   (A) only one player at a time.

   (B) two or three players at a time.

   (C) two, three or four players at a time.

   (D) only singles and doubles may be played.

3. A single game is won by the side that first scores:

   (A) 21 points (B) 11 points (C) 15 points (D) 25 points.

4. The measurements of a regulation four-wall racquetball court are:
   - (A) 35 feet in length, 22 feet in width and 15 feet in height.
   - (B) 42 feet in length, 15 feet in width and 25 feet in height.
   - (C) 45 feet in length, 25 feet in width and 18 feet in height.
   - (D) 40 feet in length, 20 feet in width and 20 feet in height.
5. The official racquet will have a maximum head length and width of:
   - (A) 15 inches by 10 inches.
   - (B) 10 inches by 12 inches.
   - (C) 12 inches by 12 inches.
   - (D) 11 inches by 9 inches.
6. To receive an opponent's serve you must stand:
   - (A) anywhere behind the short line.
   - (B) at least six feet behind the service line.
   - (C) at least five feet behind the short line.
   - (D) anywhere on the court.
7. The advantage of using the continental grip is that:
   - (A) it is the easiest to learn
   - (B) it allows you to hit all shots without changing grips.
   - (C) it allows you to hit the forehand shot from any position.
   - (D) it should be used only if you are left-handed.
8. If you have never played racquetball before one of the biggest adjustments would be:
   - (A) getting accustomed to the court.
   - (B) learning the kill shot.
   - (C) finding the best partner.
   - (D) putting the proper amount of spin on the ball.

9. The most important stroke for you to learn is:

(A) backhand (B) forehand (C) volley (D) overhead.

10. When delivering the serve, the most desirable stroke is the:

(A) backhand (B) forehand (C) volley (D) lob.

11. The first serve that one should master should be:

(A) the power serve.

(B) the lob serve.

(C) the crosscourt serve.

(D) the overhand serve.

12. In order to be a steady consistent player you must:

(A) strive to learn the most effective kill shot.

(B) strive to learn all of the basic shots.

(C) strive to become an offensive player and not rely on defense alone.

(D) strive to master the basic fundamentals and execute them properly.

13. During your partner's serve you should be:

(A) in the ready position directly behind your partner.

(B) standing up with your back to the center of the back wall.

(C) standing up with your back to the side wall inside the service box.

(D) in the ready position beside your partner inside the service box.

14. Which of the following actions DOES NOT result in a loss of service?

(A) Any served ball that hits the server's partner on the fly on the rebound from the front wall while the server's partner is in the service box.

(B) bouncing the ball more than three times while in the service box.

(C) any served ball that strikes the server's partner, or ceiling, or floor, or side wall before striking the front wall.

(D) any attempt to strike the ball on the first bounce that results in a total miss or in touching any part of the server's body other than the racquet.

15. Which of the following is not a "dead ball" hinder?

(A) any returned ball that touches an opponent on the fly before it returns to the front wall.

(B) any body contact with an opponent that interferes with seeing or returning the ball.

(C) opponent moves in the way and is struck by the ball just played.

(D) ball hits any part of the court which under local rules is a hinder.

The James-Lowell Racquetball Profile Sheet Date_______________

Name____________________ Sex M F Age____Semester____________

Classification FR SOPH JR SR (Circle one)

Self-rating: Beginner, Intermediate, Advanced.
Instructor's rating: Beginner, Intermediate, Advanced.

Instructor's Rating Score Sheet, to be scored on first 30 second trial

	WEAK	AVG	GOOD	NOT USED	INSTR	COMMENTS
Fundamentals	(1)	(2)	(3)	(0)		
Grip	(1)	(2)	(3)	(0)		
Stance	(1)	(2)	(3)	(0)		
Starting Position	(1)	(2)	(3)	(0)		
Forehand	(1)	(2)	(3)	(0)		
Follow Through	(1)	(2)	(3)	(0)		
Backhand	(1)	(2)	(3)	(0)		
Follow Through	(1)	(2)	(3)	(0)		
Footwork	(1)	(2)	(3)	(0)		

Second 30 second Trial score ____________points.

Third 30 second Trial score ____________points.

TOTAL ____________points.

Answer sheet for the James-Lowell Racquetball Knowledge Test

1. (A) (B) (C) (D)
2. (A) (B) (C) (D)
3. (A) (B) (C) (D)
4. (A) (B) (C) (D)
5. (A) (B) (C) (D)
6. (A) (B) (C) (D)
7. (A) (B) (C) (D)
8. (A) (B) (C) (D)
9. (A) (B) (C) (D)
10. (A) (B) (C) (D)
11. (A) (B) (C) (D)
12. (A) (B) (C) (D)
13. (A) (B) (C) (D)
14. (A) (B) (C) (D)
15. (A) (B) (C) (D)

☐ Right-handed

☐ Left-handed

☐ Warm-up - 30 sec.

Instructor's Rating ____________

Form A total score ____________

Form B total score ____________

Class Rank ____________

A Comparison of Tennis Skills, Knowledge, and Selected Kinematic Variables Acquired By Two Methods of Instruction

by

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ABSTRACT

The purpose of the study was to determine if there was a difference in the acquisition of tennis skills, knowledges, and selected kinematic factors between subjects taught by two different methods of instruction. One group of students (n=33) was taught by a traditional approach receiving a thorough analysis of stroke techniques, and another group (n=30) received similar instruction supplemented with related mechanical principles. An adaptation of the Miller-Broer test was administered as a pretest and posttest measure of ball placement skill. During the forehand placement tests, 20 randomly selected students from each group had two trials filmed with a LOCAM camera set at 200 frames per second to determine ball trajectory angle and ball velocity. Following the instructional unit on the forehand stroke and prior to any backhand instruction, both groups were tested on their ability to transfer their knowledge of technique and related mechanics. Pretest and posttest data were also collected for knowledge of technique, mechanics, and the application of mechanics to stroke technique. During the series of posttests, both groups were given a simple racquetball skill test to determine transfer of skill to another activity. ANCOVA was used to determine if any differences existed between the groups on the skill, knowledge and kinematic variables. Although the mechanical group scored higher on the skills tests, there were no significant differences between the groups. However, the mechanical group scored significantly higher on all knowledge variables. A comparison of kinematic variables revealed some inconsistent results with neither group displaying a favorable pattern. The authors concluded that the ability to identify and transfer specific techniques by beginning tennis players is enhanced by the learning of the underlying mechanical principles but are perhaps unable to translate this understanding into competent motor skills.

The authors wish to express their gratitude to the Office of Research Development and Administration, Southern Illinois University at Carbondale, for their funding of this study.

Physical education instructors have long adhered to a teacher-centered approach to the teaching of physical activities where the teacher explains and demonstrates, the student imitates and drills, and then the teacher evaluates. However, this traditional approach to the teaching of physical skills seems to involve only the psychomotor domain, and almost totally ignores the cognitive and affective domains on the part of the students.

If we are to educate the learner in the basic elements of movement (e.g. space, force, time and flow) in order to create more effective and efficient movement and learning, the learner must understand and be able to apply the basic principles that govern all movement. Therefore, it follows that performance should be facilitated when the individual understands what he or she is doing and why it is being done. The learner should be able to make application of mechanical principles in order to facilitate the learning process.

Many authors have reported that the additional knowledge of mechanical principles did not increase performance in several motor skill activities: such as one-hand push shot in basketball (Halverson, 1949); ball rolling, catching and archery (Colville, 1957); bowling (Coleman, 1967); gymnastics (Fath, 1968); and badminton (Weis, 1970). Frey (7) found that the group having an elaborate analysis of form had higher scores on volleyball tests, but exhibited lower scores than the group without this analysis in tests of tennis and rhythms.

However, several authors have reported better performances by persons who had additional knowledge of mechanical principles than by persons without such knowledge. Among the activities investigated were swimming (Barrett, 1957); volleyball, basketball, and softball (Broer, 1958); standing broad jump and softball throw (Montgomery, 1961); and intermediate swimming (Mohr and Barrett, 1962).

In a beginning tennis class (Cobane, 1959), one group was taught by the traditional method (demonstration, explanation, practice, and correction) and the other group was taught similarly, but with the addition of mechanical principles. Although there was no difference in skill level between groups, the experimental group was superior in knowledge and understanding.

A possible reason for the discrepancies in research findings was cited by Singer (20). He stated that the problem may lie in the methodological differences in experiments which raised the questions, (1) does the experimental group get the same amount of direct practice as does the control group, with the experimental group getting additional time to learn mechanical principles? or, (2) do both groups spend the same amount of time in class, with the experimental group having to decrease direct practice in order to learn the principles? It would seem that the first example would favor the experimental group, while the second example would favor the control group.

In the present investigation, an attempt was made to control these problems by insuring that both groups had the same amount of direct practice, and that both groups also spent the same amount of time in instruction.

Procedures

The purpose of this study was to determine if there was a difference in the acquisition of tennis skills, knowledges, and selected kinematic factors between subjects taught by two different methods of instruction. Sixty-three (63) college students from two beginning tennis classes served as subjects. Thirty-three students, 11 female and 22 male, were taught by the traditional approach (teacher explains and demonstrates, students practice, teacher evaluates) and received a thorough analysis of each stroke technique. Another thirty subjects, 11 female and 19 male, also received the thorough stroke analysis but it was supplemented by mechanical principles. These groups will be called the traditional and mechanical groups respectively. Both groups received handout materials explaining thoroughly the stroke techniques, identical in content, except that the material given to the mechanical group contained a series of letters and numbers following each statement of technique. These letters and numbers corresponded to a list of mechanical principles that was given to the mechanical group on another handout. This group was then instructed as to how these principles applied to the prescribed stroke techniques. Some individual applications were given to each student in the mechanical group during their practice. The actual time spent on these applications was carefully monitored and an equivalent amount of time was spent with the traditional group on their techniques. These classes met two days a week, two hours per session for eight weeks. Both classes were taught by the same team of four tennis instructors.

The SIU adaptation of the Miller-Broer test (utilizing an automatic ball deliverer and additional scoring zones) was administered before and at the conclusion of the course of instruction to measure forehand and backhand placement skills. During the forehand placement tests, 20 randomly selected students from each group had two (out of 14) trials filmed with a LOCAM camera set at 200 frames per second and located 75 feet from the subject on a line running through the baseline and therefore, perpendicular to the line of flight of the ball. Previous studies have assessed skills through the use of judges or some form of subjective evaluation. It was the intent of this study to analyze selected kinematics of precourse and postcourse using cinematographic procedures.

Standard film reduction techniques were used to obtain kinematic data related to ball placement. X, Y coordinates for the racket and the ball at impact and at five frames thereafter were obtained from the projected film and automatically recorded from a Graf Pen digitizer interfaced with an IBM keypunch. These coordinates provided the input for a FORTRAN program which computed the ball trajectory angle and the ball velocity.

At the end of the instructional unit on the forehand stroke, and prior to any backhand instruction, both groups were asked to identify and list the techniques involved in the backhand stroke. The purpose of this was to examine any differences in the groups' ability to transfer their knowledge.

The two groups were tested at the beginning and at the conclusion of the course of instruction on the following variables: forehand and backhand skill placement, knowledge of tennis scoring, etiquette, rules, technique, mechanical principles, and the application of mechanical principles to stroke technique, and the film subgroups were measured on precourse and postcourse ball trajectory angle and velocity. During the series of posttests both groups were given a simple racquetball skill test to see if there was any difference between the traditional and mechanical groups in their ability to transfer skill to another activity.

Since the groups were not homogeneous on many pretest variables, an analysis of covariance (ANCOVA) was used to determine differences between the two groups on posttest variables.

Results

Descriptive data of the major variables are presented in Table 1. An examination of the means on pretest and posttest variables reveals that the mechanical group was superior to the traditional group on the pretest and posttest skill variables while the traditional group scored higher on the pretest knowledge variables, with a reversal occuring on the posttest. Both groups exhibited similar tendencies on the pretest kinematic factors with the traditional group demonstrating a greater (but less desirable) ball trajectory angle. On the posttest, however, the traditional group improved on ball angle while the mechanical group digressed slightly. Both groups gained in ball velocity with the traditional group exhibiting the greater velocity.

Table 1

Means and Standard Deviations of Selected Variables

Variables	Pretest				Posttest			
	Mechanical		Traditional		Mechanical		Traditional	
	$\overline{X}$	sd	$\overline{X}$	sd	$\overline{X}$	sd	$\overline{X}$	sd
Skill Variables								
Forehand	35.3	14.6	32.0	12.3	49.6	14.7	41.2	13.2
Backhand	34.2	14.0	26.4	12.9	38.0	14.6	36.4	12.5
Total	69.6	25.2	58.4	21.4	88.3	25.9	77.6	20.8
Racquetball Transfer					17.2	4.7	16.8	5.3
Knowledge Variables								
Multiple Choice	8.5	2.5	8.3	2.1	31.4	3.6	30.3	5.3
Short Answer	7.9	3.4	10.1	3.1	37.6	9.2	20.2	7.3
(Direction, Velocity, Whys)								
Mechanics	5.7	2.5	6.9	2.6	21.0	6.0	10.4	4.5
Technique	2.2	1.2	3.2	1.0	16.6	4.1	10.1	4.4
Written Total	16.4	5.3	18.4	4.1	69.0	11.4	50.5	11.5
Kinematic Variables								
Ball Trajectory Angle (Degrees from Horizontal)	16.3°	7.6°	19.7°	13.8°	17.4°	9.4°	12.4°	6.2°
Ball Velocity (ft/sec.)	68.3	20.0	70.6	14.7	79.5	16.8	86.3	21.7

Using pretest scores as covariates, significant F ratios ($p < .05$) were found between groups on the following variables, with the mechanical group clearly superior: total short answer, short answer technique, short answer mechanics, written total. The traditional group had a significantly lower ball trajectory angle. The analysis of covariance summary table for these variables is presented in Table 2.

Significant differences were also found between the groups on the tests of knowledge transfer to the backhand stroke, in which the mechanical group was clearly superior. The ANCOVA summary table for these transfer variables is found in Table 3.

Discussion

While the gain in the skills test scores was greater for the mechanical group on the forehand and greater for the traditional group on the backhand, these differences were not significant. Both groups were equal in gain for the total skills test. The significant differences found between the groups on the knowledge variables, indicated that the mechanical group did benefit from the instruction on mechanical principles particularly in their ability to list and identify more of the prescribed techniques of the strokes and the related principles and in their ability to transfer their knowledge to related skills. It was also noted that the mechanical group was able to list mechanical principles supporting each of their listed techniques. It would appear then, that the length of the course was sufficient to effect a difference between the groups in cognitive abilities but that the time period was insufficient to cause a significant change in skills tests that might be attributable to this acquired cognitive ability. The low and extremely variable skill level of beginning tennis players may preclude the possibility of translating knowledge of proper techniques and mechanical principles into movement patterns reflective of this knowledge.

Table 2

ANCOVA for Posttest Scores

Source	df	MS	F	p
Short Answer Total (Velocity, Direction, Whys)				
Model	2	2334.98	35.40	0.0001
Pre SA	1	51.68	0.78	0.3798
Group	1	4618.29	70.01	0.0001
Error	58	65.97		
Short Answer Mechanics				
Model	2	841.55	29.90	0.0001
Pre Mech	1	8.89	0.32	0.5762
Group	1	1674.21	59.47	0.0001
Error	58	28.15		
Short Answer Technique				
Model	2	328.01	17.97	0.0001
Pre Tech	1	18.03	0.99	0.3244
Group	1	637.98	34.96	0.0001
Error	58	18.25		
Total Written Exam				
Model	2	2920.65	25.00	0.0001
Pre WrTo	1	216.14	1.85	0.1790
Group	1	5625.17	48.15	0.0001
Error	58	116.83		
Ball Trajectory Angle				
Model	2	117.60	2.63	0.091
Pre Ball Ang	1	31.13	.70	0.412
Group	1	204.06	4.56	0.042
Error	27	44.78		

Table 3

ANCOVA Summary Table for Transfer Variables

Source	df	MS	F	p
Knowledge Transfer				
Backhand Techniques				
Model	1	114.56	21.29	0.0001
Error	61	5.38		
Backhand Mechanics				
Model	1	133.54	47.70	0.0001
Error	61	2.80		

Although the two kinematic variables investigated in the present study are related to ball placement (a factor in the forehand skills test) they are insufficient to determine differences that might exist between the two groups in overall efficiency of the forehand stroke. Such a determination would require the analysis of numerous kinematic factors for the entire stroke.

Although the traditional group exhibited a greater gain in mean ball velocity than the mechanical group, this difference was not statistically significant. However, the groups were found to differ significantly in the ball trajectory angle with the traditional group decreasing the trajectory angle on the posttest. The students were taught to use a flat stroke and to hit the ball deep in the opposite baseline. Because the placement of the ball will be influenced by spin as well as force impulse and ball trajectory we cannot interpret these results as being favorable or unfavorable. Since the filmed trials were only two out of fourteen for each subject, and considering the degree of variability between the subjects and trials, the two filmed sequences may not be representative of each subjects' performance. In fact, if the mean values of the ball angles and velocities of the study are substituted into the standard formula for determining the range of a projectile, the predicted distances are well beyond the scoring area of the placement test. For the filmed trials this may indicate the traditional gorup is stroking too hard and too low without adequate top spin.

Conclusions

Within the limits of this study, and as a result of analyzing the data collected, several general conclusions were made and attributed to the subjects in this study.

The ability to identify and list specific techniques of skills by beginners is enhanced by the learning of the underlying mechanical principles that those techniques are based upon. The ability to transfer one's knowledge of technique to another skill in the same sport is influenced more by the learning of the underlying mechanical principles than by learning only the techniques under a more traditional teaching method. Total tennis knowledge, as assessed by a written examination including scoring, etiquette, rules, technique, and the application of mechanical principles may be enhanced more by learning the mechanical principles than might be learned in the more traditional approach.

The investigators believe there is still some question regarding the ability of beginning level students to assimilate their new understandings into competent motor skills.

Recommendations for Further Study

Based upon the findings of this study, the following recommendations are suggested:

1. The study should be repeated under a more longitudinal design which might permit the development of skill patterns reflective of the cognitive levels of the groups.
2. A similar study conducted with intermediate players might reveal a relationship between initial skill level and the ability to translate knowledge into efficient motion.
3. A thorough kinematic analysis of each subject would, in a pretest/posttest design, more adequately determine skill acquisition.

BADMINTON FOOTWORK

by

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Abstract

Footwork in badminton is concerned with reaching the shuttle in as few steps as possible while maintaining good balance and body control. The beginning of good footwork is an alert waiting position. From this ready position. one must be able to move quickly as soon as the direction of the return is determined. Take small, bouncy steps, shuffling or sliding into position to hit. Ideally, any shot can be intercepted in two or three steps. Reaching for the shuttle with the dominant arm and leg saves one time, plus the subsequent push-off on this leg will aid in a swift recovery in changing directions. From the ready position, the non-dominant foot is always the pivot foot and the dominant foot the leading one. From center court, as soon as the direction of the return is determined, pivot, then lead with the dominant foot taking a step-close or skipping action with the feet over only on the backhand, never on the forehand. As the last step is made with the leading foot and the shuttle is contacted, push off with the lead foot propelling one's self back towards center court.

If speed alone is desired, a variation of the crossover step is possible. It is similar to the track sprinter's start in which the base of support is removed and one falls in the desired direction. For example, to move to the left, a right-handed player moves the left foot back as he pivots and crosses over with the right foot. In effect, the left foot which is a base of support is removed and the player falls to the left.

Badminton is a game involving a striking technique and strokes that vary from relatively slow to quick, deceptive movements. Since the shuttlecock does not bounce and must be played in the air, it makes for a fast game requiring quick reflexes and some conditioning. Indeed, when played by experts, badminton is considered to be the fastest court game in the world.

Footwork is an essential fundamental skill of badminton. It gets you into the best possible position to execute your shots. The badminton shuttle rarely comes to you, thus you must move into position to hit the shuttle. Movement on the court is concerned with reaching the shuttle in as few steps as possible while maintaining good balance and body control. The ability to move to the shuttle quickly and effortlessly is important for every player to acquire. Yet, it is surprising how few players actually emphasize this part of their game. Americans especially seem to have less training in foot-related activities, such as, soccer and ballet.

The ideas on footwork to be discussed are my adaptations of principles learned from experience, observation and discussion with other badminton enthusiasts. Donald Kerr of Tulane University in New Orleans is the primary source of the thoughts on the "gravity method". Mr. Kerr is an amputee who plays badminton and moves very well on the court with an artificial leg.

The purposes of any form of footwork are: (1) to get to the shuttle as soon as possible; (2) to maintain body balance at all times; and (3) to use as little energy as possible. Footwork should become habit and be a virtually automatic aspect of your game. But initially, it will take repetition and practice, along with some additional thought during play.

Actual movement on the court is discussed in two forms: the basic method and the "gravity method".

READY POSITION

The beginning of good footwork is an alert ready position. In the ready position, keep the feet spread shoulder width and bend the knees slightly with the weight on the balls of the feet. The racquet head should be held up, in front of the body, slightly on the backhand side. From this position you are now ready to hit from either side as well as move forward or backward to attack or retrieve. It is very important to try to recover to this position after every shot so that you can move to the next shot. The best court position is center court which is equidistant from the four corners. This basic position on the court will enable you to reach most shots with less effort and in less time. From the ready position, you must be able to move quickly as soon as the direction of your opponent's return is determined. Small bouncy steps should be taken, shuffling or sliding into position to hit. Ideally, any shot may be intercepted in two or three steps. The following techniques cover movement to the net, movement sideways, and movement backwards.

BASIC METHOD

The basic method is used when less distance is to be travelled; for example, when the shuttle can be reached in approximately two steps and one does not have to move to the extreme corners of the court.

From the ready position, the nondominant foot is always the pivot foot and the dominant foot the leading one. Reaching for the shuttle with the dominant arm and leg saves time and the subsequent push-off on this leg aids in a swift recovery in changing directions.

From center court, there are basically six directions you will need to move to. They are: (1) up, right to the net; (2) up, left to the net; (3) left to the sideline; (4) backhand to the baseline; (5) forehand to the baseline; and (6) right to the sideline. In each case, as soon as the direction of the return is determined; pivot, then lead with the dominant foot taking a step-close or skipping action with the feet close to the floor. Cross your feet over only on the backhand, never on the forehand. Figures 1 and 2 illustrate the basic footwork used to intercept the oncoming shuttle. As the last step is made with the leading foot and the shuttle is contacted, you should push off with the lead foot propelling yourself back towards center court.

GRAVITY METHOD

If more speed is desired or greater distance is to be covered, the "gravity method" is suggested. It is similar to the track sprinter's start in which the base of support is removed and one fails in the desired direction. Thus the crucial contribution of gravity is in starting and reversing one's movement.

Moving to the Net

From the ready position, a three-step pattern is sufficient for most players to reach the net. Whether moving up to the forehand or the backhand, the non-racquet leg is pulled back and in, from the ready stance, allowing the body to fall forward. At the same time, the racquet leg leads in the proper direction followed by the non-racket leg in a step-close action. The third step is taken by the racquet leg which is extended and planted in front of the body for the shot.

In order to divide the work load evenly between the two legs, pull the trailing leg up under the body and push back with both legs. Bringing both feet up straightens the body, actually causing it to fall back and make the return to center less tiring. The return in both cases is a three

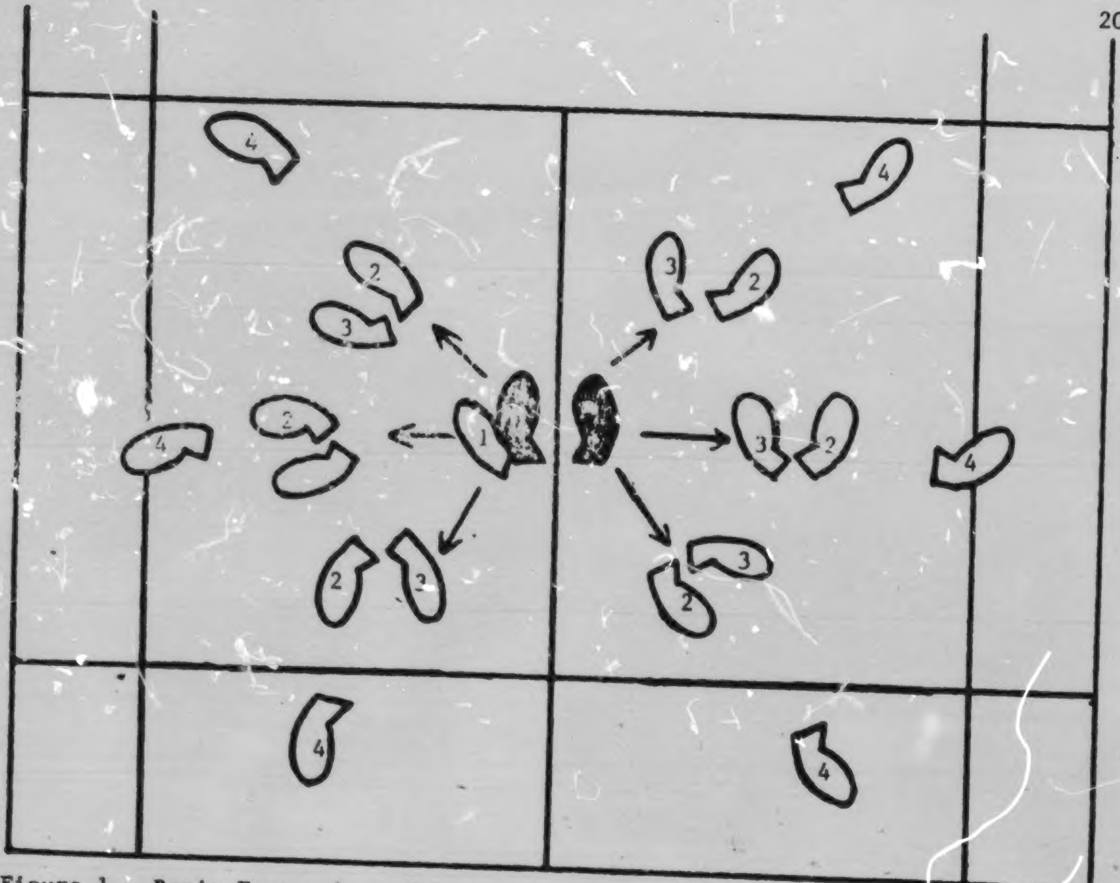
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Figure 1. Basic Footwork used to intercept oncoming shuttle for right-handed player.

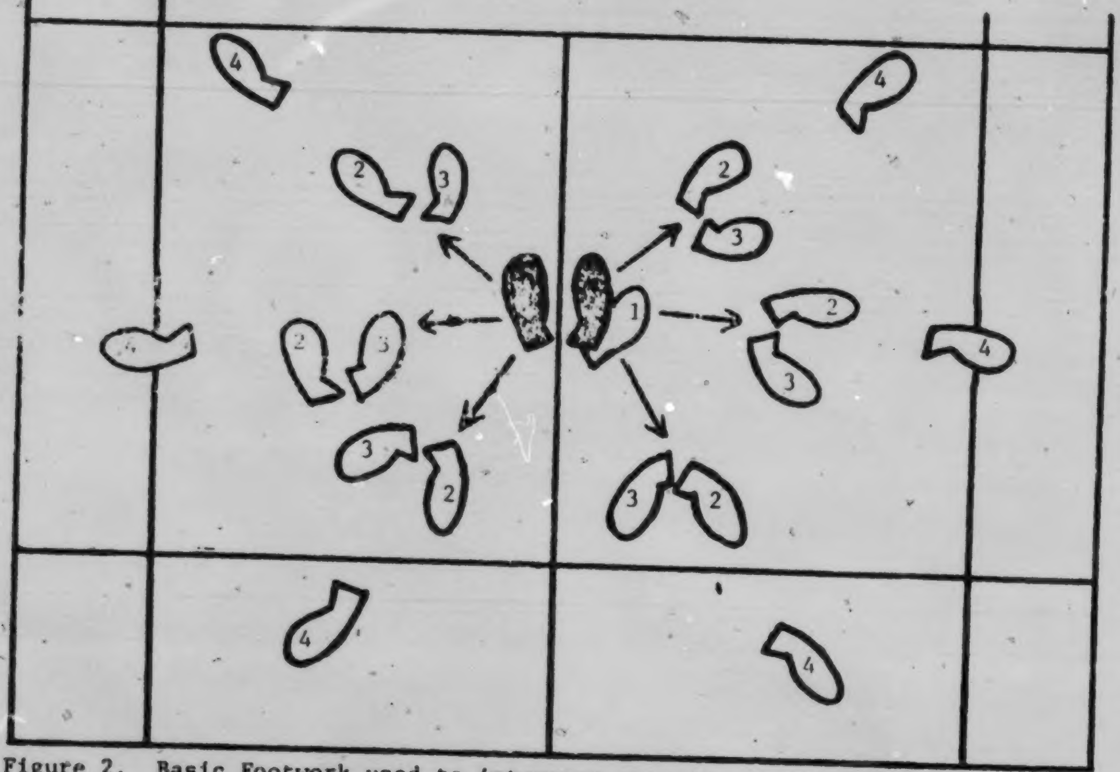
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Figure 2. Basic Footwork used to intercept oncoming shuttle for left-handed player.

step pattern; racquet-leg, other leg, racquet-leg.

Moving Sideways

To the racquet side, pull the non-racquet-leg in from the ready stance and propel the racquet leg into a side step followed again by the non-racquet leg in a step-close action. The third step is taken by the racquet leg which is extended sideways in the direction of the oncoming shuttle.

To the other side, the non-racquet-leg is pulled in even farther and the racquet leg is propelled into a cross-over step. Again the non-racquet leg shuffles or slides in a step-close fashion and the racquet-leg follows with the third step in reaching for the shuttle.

The return to center court in both cases is the same three-step pattern as before: racquet-leg, other leg, racquet-leg.

Moving Backwards

The three step pattern for moving backwards is very similar to moving sideways. However, whether forehand or backhand, the body must turn slightly in the direction to be moved.

As the body turns toward the forehand, the non-racquet foot is moved in and slightly forward. Almost simultaneously, the racquet leg reaches in the proper direction. The racquet-leg leads while the non-racquet-leg catches up in a shuffling or step-close action. The racquet-leg is again propelled toward the direction of the oncoming shuttle. The racquet-leg catches up in a shuffling or step-close action. The racquet-leg is again propelled toward the direction of the oncoming shuttle.The racquet-leg is planted with the body sideways to the net and a normal overhead stroke is made.

For the backhand, the non-racquet foot pulls in and allows the racquet-leg to cross over and lead with the first step as the body turns in that direction. A shuffle step by the non-racquet-leg followed by a third step with the racquet leg puts the body in position to execute the backhand overhead stroke.

As the shot is made, the non-racquet-leg is pulled back under the body causing it to fall forward and aiding in the return to center court. The return is again a three-step pattern.

SUMMARY

Both of the footwork methods are accepted and used to some extent by most experienced badminton players. They are quite similar except for the use of gravity in starting and changing directions. The gravity method also allows the non-racquet-leg to aid in changing direction. Ideally, one would probably use both methods during the course of a match. The basic method is sufficient when the shuttle is relatively close. But when necessary to lunge in close to the net or retreat for a deep return near the baseline, the gravity method is almost essential.

The forehand and backhand drives provide an excellent opportunity to introduce footwork because the drive is generally taken to the right or left of center court and between shoulder and knee height. Thus, it stresses moving to the shuttle by shuffling or sliding the feet into position. From the ready position, as soon as the direction of the return is determined; pivot, reach with the dominant foot shuffling or taking a step-close or skipping action with the feet close to the floor. Cross the feet over on the backhand, but not the forehand. As the last step is taken, push off and propel yourself back towards center court.

In the classroom situation, probably only a brief period will be spent on footwork due to limited time and space. However, repetition and practice to develop court speed and efficiency of movement are essential for the advanced player.

POSTER PRESENTATIONS

SELF INSTRUCTION WORKBOOK FOR

BEGINNING SQUASH

SELF INSTRUCTION

OBJECTIVES

CONTENT

FEEDBACK

The Development of an Individualized Self-Instruction Workbook for Beginning Squash

by

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Abstract

During the Spring and Summer of 1978 a project was undertaken at McMaster University to develop a self-instruction workbook for beginning squash.

Undergraduate Physical Education students enrolled in beginning squash classes participated in two, two-hour classes per week for six weeks. It was apparent to the investigator that a variety of factors could be better accommodated if the students had a workbook from which they could progress through the majority of the course materials. These factors included the problem of more than two students assigned to each court, the presence of a variety of squash skill levels in each class, and the difficulty in communicating to the students on a regular basis due to the physical isolation of squash courts.

The basic format of the workbook includes the sequential presentation of squash skills. Each new squash skill is introduced with a description, and key points to note followed by drills. Accompanying each drill are performance tasks which each student is expected to complete before proceeding to the next new skill.

Utilization of the workbook frees the instructor from the traditional teaching role and allows the student to receive individual attention when needed.

Many teachers and coaches of physical activity are constantly seeking more effective methods of helping people learn new skills. A review of the literature reveals a continuous search for various methods of instruction. One teaching method which has received attention, and has proven to be equally as effective as a traditional teaching method, is that of an individualized self-instruction style (Inglis, 1977).

During the Spring and Summer of 1978, a project was undertaken at McMaster University in Hamilton, Ontario to develop a self-instruction workbook for beginning squash. The intent of this project and manual development was to have an additional resource for the students to use that would individualize the learning pace, free the instructor from the traditional command teaching style and be an effective tool in the learning of a skill.

It is the intent of this paper to present:

1) a selected review of the literature related to self-instruction methods;
2) the purpose and various phases of the squash program which were developed
3) an overview of the basic workbook format with a detailed examination of a particular unit on the forehand drive; and
4) initial program results.

The concluding paragraphs will deal with future program developments which can be directed towards effective teaching and learning situations.

Review of Related Literature

The literature provides support for various teaching innovations as well as descriptions of partucular teaching methods. Cassidy et al. (1974)

for example, stress the need to seriously change the methods of teaching which are used in physical education programs. The programs they advocate focus on the individual, his uniqueness of self, and his needs. Singer and Dick (1974) present a systems approach to instructional design which is a logical, conceptual and practical method of planning effective programs. The basic characteristics involve the assessment of student needs and available resources, and the utilization of specific goal and behavioral objectives with a means of evaluation. The systems approach incorporates many aspects of the learning process in an attempt to accommodate individual differences.

Individualized methods of instruction incorporate a systems approach, programmed instruction techniques, and learning theory. For instance, Green (1962) and Lysaught and Williams (1963) outlined the characteristics of self-instruction materials. Goals and objectives are set prior to the beginning of the program, material is presented in an organized logical sequence, each unit of material requires the student to make an overt response, each unit must be mastered before continuing to the next and immediate feedback is necessary to indicate to the student the adequacy of the response. The feedback given to the student is what Robb (1972) views as the "heart of skill-learning".

For the student, a self-instruction program individualizes the learner's experience, enhances his readiness and alertness by providing the student with an active role, and maintains a level of motivation through constant reinforcement (Lysaught and Williams, 1963).

The unique feature of the self-instruction method is that it allows the student to work at his own learning pace. A self-instruction method is in no way an attempt to replace the teacher; rather, the objective is to provide for the teacher, a basis of material, and a method and organization from which the student may proceed (Green, 1962).

Keller (1974) describes the instructor as "manager of learning" in an individualized structured learning environment. The instructor becomes a member of the system; preparing, monitoring, altering and providing feedback within the program.

It was the above literature that provided the foundation for the development of the squash workbook.

Squash Project

The purpose of the project was to develop a workbook which would aid students enrolled in the undergraduate beginning level squash classes in progressing through the majority of the course materials. These students participate in two, two hour classes per week for six weeks. To the project co-ordinator (who is also one of the squash instructors), there were a number of factors which encouraged preparing such a workbook. These factors included:

1) a variety of squash skill levels in each class;
2) the physical isolation of each squash court causing difficulty in group instruction and individual correction; and
3) the fact that class sizes dictate more than two students to a court.

These factors, coupled with personal interest in designing more effective teaching and learning practices, provided the impetus for the project.

Project Phases

In developing the workbook, there were four main phases. The initial phase was that of identifying the units or areas to be included and the specific content of the units. Once a draft of the units had been written, the second phase of administering the units to a variety of beginner and advanced level squash players was undertaken. The third stage of revision took place after the selected squash players had used the workbook units. The revisions included additions, deletions, and the rearrangement of the unit materials. The final phase was identified as the first edition of program usage. During this phase, four classes of squash students used the prepared workbook in a self-paced instruction teaching and learning environment.

Workbook Format

Before an explanation of the workbook format is given, a summary of the general descriptive workbook objectives will be outlined.

The objectives are:

To allow a student to progress at his own pace.

To allow a student to receive help from the instructor when needed.

To allow a student to know the materials expected for course requirements.

To allow a student to review the course material at any time.

To allow a student to monitor his individual progress.

To place the responsibility of learning on the student.

To place the instructor in a role to monitor individual progress, to provide feedback to the student and to help the student when necessary.

The workbook is organized into various units which cover a sequential presentation of squash skills. Each unit includes information organized under the following headings of: basic play, body position, footwork and weight transfer, the swing, racket face and notes. Following these headings related to stroke mechanics are specific drills which serve to give practice for the specific stroke. Each drill has a performance task which provides a self-test guideline as to the adequacy of the student's slill level. Once the student performs the performance task, he progresses to the next unit.

A student may first prepare for a unit by reading the material prior to class time. During class time, the student works on the specific drills and progresses as the skill level increases to meet the tasks. It should be noted that because the instructor can closely monitor the student's progress in certain cases, a student may be encouraged to progress to the next unit before the present unit's tasks are completed or, on the other hand, a student may be encouraged to move to the advanced drills at the end of the manual. A degree of flexibility must prevail in order to suit the content to the individual's needs and abilities.

A more detailed explanation of a particular unit, the forehand drive, will be discussed to further the reader's understanding of the worbook content.

The Forehand Drive

The forehand drive is part of Unit I on Drives. An exerpt from the workbook on the forehand drive may be found at the end of this paper. A student would begin this unit by reading the information given on basic play. Specific points of importance related to the body position, footwork and weight transfer, the swing, and racquet face would be read next. Up to this point, the student does not have to be in the court. Reading can be done at home or in the viewing gallery if the courts are occupied. The next heading in the workbook is that of notes. In this section, the student would read key phrases related to the stroke as well as shadowing a few practice strokes. It is in this section that a student would also be given key points related to stroke execution. For example - can you feel the weight transfer? A student who feels comfortable with the performance task would continue to drill #1.

Drill #1, forehand down the wall drive, outlines that the drill is to be done individually, the purpose of the drill is - to practice hitting forehand drives down the wall, instructions accompanied by a court diagram on how to do the drill, points to note and a performance task.

> Performance Task - to drive the ball to the
> front wall, using the forehand stroke,
> 20 times. Remember to catch the ball
> after each hit.

Check when completed ☐

A student who successfully completes the task would move on to drill #2.

As students progress through the workbook, they work in small groups with each drill specifying whether the student works on his own or with a partner.

Initial Program Results

To date, there has not been any formal data collection to measure the student's psychomotor or affective behavioral domains. Informal comments have been collected as the students recorded their impressions and suggestions in the workbook throughout the class sessions. The feedback that the instructors received and which the course evaluations supported is that the students welcome the chance to progress on their own; they feel comfortable using the workbook to learn new skills and they understand the role of the student and instructor. It would be an interesting study to measure the effectiveness of the individualized self-instruction style compared to a traditional command style.

Concluding Remarks

When implementing any innovative style of teaching, it is important to take the time to explain the methodology to the students.

A thorough description at the beginning of the course will alleviate any misunderstandings which may occur. In the case of this particular work book, which has been described, the students were keen to try a 'different approach'. For many students, it was the first time that they had to take an active part in learning new material.

Also to be considered is the degree of teacher involvement in an individualized self-instruction teaching, learning environment. In this case, the instructors make themselves available to answer questions, to demonstrate, to assess skill levels and to encourage the students to move to the next unit or work longer on specific skills.

A final comment is that of incorporating visual aids into the course material or on-court demonstrations, and tournament play for the students. These additions help teach the proper skills and maintain a high level of motivation in the class.

There are ways of presenting new skills and information which will create an effective learning situation for the student. It is a challenge for the teacher and coach of physical activity to develop these styles which will be most effective, and a challenge that should be pursued.

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Appendix

Unit 1

DRIVES

Basic Play:

Forehand and backhand drives are the most common shots played in squash. Drives are considered to be the shots which allow for 'hitting to good length' on the court. Forehand drives are those shots executed on the racket side of the body; backhand drives are executed on the non-racket side of the body.

FOREHAND DRIVES

Body Position

- turn to face square to the side wall.
- watch the ball at all times.
- bend your knees slightly, feet shoulder width apart for good balance.
- racket head up and other hand in comfortable balance position.

Footwork and Weight Transfer:

- step forward with your front leg as you stroke through the ball.
- keep your knees bent to stay down with the ball.
- as the shot is executed, there should be a natural transfer of weight from your back leg to your front leg.

The Swing:

- early stroke preparation is a must
- keep your wrist cocked (racket head above the level of the wrist) and elbow bent, the racket head should be at a height between the shoulder and the ear or lower.
- the forward swing of the racket should include the elbow leading the racket to a place in front of the lead leg where the ball is contacted.
- the wrist pronates prior to contact with the ball.
- the ball should be hit off the lead leg with a straight arm.
- on the follow through, the racket is brought up to shoulder height, again with the elbow bending to keep the racket in close to the body.
- the entire swing should be one smooth, continuous motion
- return to the ready position

Racket-Face:

- the ball should be contacted with the racket face sloped back slightly. This is an 'open' face and will allow the ball to travel upward, thus eliminating hitting the ball into the tin.

Notes:

The above description should help you to hit forehand drives down the wall.

Before actual hitting, shadow a few practice strokes. To shadow a stroke is to swing through a few forehand drives to begin getting used to the feel of the stroke without hitting the ball.

Check when you feel you can correctly shadow a forehand drive. ☐

Can you feel the weight transfer?

Can you spot where the racket face should contact the ball?

Are your knees bent to keep your weight low?

Is the racket path preventing a dangerous backswing or follow-through?

Is the total stroke executed smoothly?

Performance Task:

Shadow a few forehand strokes with a stiff arm. Now, shadow with forearm rotation (pronation). Can you feel the difference? The forearm pronation will be key in developing a proper stroke.

Check when completed ☐

If you wish to have instructor watch you shadow the forehand drive, ask now. If you feel you are ready to try some forehand drives, you should now progress to drills #1 and #2.

TENNIS INSTRUCTIONAL AIDS

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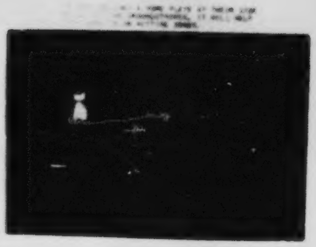

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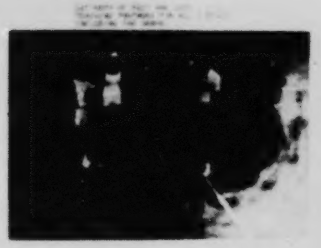

TENNIS INSTRUCTIONAL AIDS

by

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ABSTRACT

The question of instructional aids being utilized in a tennis class always raises some eyebrows among teachers. The tennis industry is flooded with innovative gadgets and mechanical devices which are advertised persuasively. A common obstacle to the use of such aids is cost. Most instructional programs have limited amounts of funds available and must use these funds wisely.

There are several tennis aids and devices which can be constructed from materials readily available at a minimal cost or no cost at all. Items such as milk cartons, tennis ball cans, and corrugated shipping boxes to name a few, can be put to good use.

The purpose of this poster presentation is to identify some materials and sources for the construction of tennis instructional aids and those which have proven successful in an instructional setting.

Although instructional aids are not new to the teaching profession, the question of instructional aids being utilized in a tennis class always raises some eyebrows among teachers. The tennis industry is flooded with innovative gadgets and mechanical devices which are advertised persuasively. A common obstacle to the use of such aids is cost. Most instructional programs have limited amounts of funds available and must use these funds wisely. Stroking technique and tennis interest can be developed indoors as well as outdoors without the use of courts. This can be accomplished by the construction of many inventive teaching aids that one can prepare from materials readily available at a minimal cost or no cost at all. This article recalls the familiar adage "one man's trash is another man's treasure."

While teaching aids are an important part of good tennis instruction, it should be remembered that, used alone or for prolonged periods of time, they may hinder rather than help the student. The following paragraphs present a few of the tennis aids which can be constructed from milk cartons, tennis ball cans, old bed sheets, and corrugated cardboard boxes with a short description of their importance in the instructional program. Many of the ideas presented in this article are taken from a publication of the AAHPER entitled, "Ideas For Tennis Instruction."

Targets

A variety of targets can be used to develop interest, emphasize targets, and develop stroking accuracy. How many times have we seen a student try to hit an overhead so hard without placing the ball that the opponent merely blocks the ball back giving the smasher one more chance to make an error. By using targets and emphasising the point that an ounce of placement is worth a pound of power, the student will soon realize the importance of hitting the overhead at three quarter speed and placing it.

Bed sheets, preferably colored, provide excellent targets. In addition, the bed sheets may be folded in decreasing sizes as accuracy improves. Other materials such as cardboard boxes can be cut into several shapes and used in the same fashion as sheets. Sources for the construction of targets from sheets include the housekeeping office of colleges, universities and hotels.

Elbow Restrictor

A common backhand trouble spot occurs when the student swings from the elbow only - the "elbow poke." The result is a very short and abrupt swing. A cardboard milk container with the ends cut off is placed over the elbow joint. It restricts flexion, thus encouraging proper action when executing the backhand stroke. The size of container (quart, half-gallon, gallon) is dictated by the girth of the student's forearm.

Footprint Guides

As one of our best teaching professionals, Vic Braden, has said, "the greatest strokes in the world are no good at all if you don't get to the ball first." It has been found very useful to cut out templates of footprints from cardboard and place them on the floor to show approximate placement of feet for different strokes. The footwork for the serve and approach to the net for first volley are one example of their use.

Wrist Positioner

A neophyte player when first instructed in the art of volleying will play balls below waist level by letting the racquet head drop below the level of the wrist. Another common error occurs when the speed of the approaching ball increases. The student inadvertently begins to play their backhand volley by turning the face of the racquet over and using the forehand side. Both errors can be alleviated by attaching an elastic cord to the racquet head and wrist of the hand holding the racquet. This emphasizes position of racquet head in relation to arm and wrist.

Tennis Ball Can Under The Arm

A tennis ball can with string passing through the can and hung around the neck can be neatly tucked under the arm of a player to enable the feeling of proper distance of arm from side when stroking a forehand. If the arm moves too far away from the body, the can merely falls a few inches before being caught by the string.

Directing The Ball

Several arrows cut out of cardboard are very useful in helping answer the students question of "How do I hit crosscourt or down the line?" The arrows are placed on the court pointing straight ahead for a down the line shot or crosscourt for a crosscourt shot. By having the student swing along the shaft of the arrow, adjustments of feet, body position, and point of contact become automatic.

Teaching aids are an important part of good tennis instruction. As stated earlier, they can motivate interest and improve stroking technique. Inclement weather need not deter lessons from taking place as some of the best teaching is done indoors in confined areas. It is here that distractions are minimal and group control more easily achieved. A carefully programmed unit on tennis, combined with teaching aids will enable students to learn more quickly.

STROKING ERRORS COMMITTED IN CHAMPIONSHIP TENNIS COMPETITION

L.D. HENSLEY - UNIVERSITY OF GEORGIA

The purpose of this study was to [illegible] the stroking errors committed by collegiate tennis players in championship competition. Subjects in the study were participants in the [illegible] NCAA Tennis Championships. Data was collected during direct observation of [illegible] tournament matches. The principal variable of interest, stroking error, was defined as any [illegible] shot in which the ball did not land within the appropriate court boundaries. [illegible] resulted in the ball going into the net [illegible] but did not distinguish between forced and unforced errors. [illegible] were [illegible] the position of the hitter in the opponent's [illegible] whether a forehand or backhand stroke was attempted, whether [illegible] was directed crosscourt or down the line [illegible] to the outcome of the stroke (the ball was either hit into the net, long or wide). In order to compare frequency of errors relative to the [illegible] information was obtained on all shots that resulted in outright winners [illegible] which the opponent was not able to hit a return shot. Backhand down-the-line shots were the most predominant cause of stroking errors, while crosscourt forehand shots resulted in the fewest number of errors. Down-the-line shots, both forehand and backhand, produced over one and one-half times as many errors as did crosscourt shots, yet resulted in an equivalent number of outright winners. The forehand strokes proved to be the most reliable for [illegible] performers, resulting in approximately 25% fewer errors than backhand strokes. Shots hit into the net produced 52% of all errors, while those going long or wide produced [illegible]% and [illegible]% respectively. In regard to the service, it was found that match winners put [illegible]% of their first serves into play, compared with 57.5% for the losers. Analysis of the data indicated that match winners hit 1.3 times as many winning shots as did match losers, while committing only [illegible]% as many stroking errors. An evaluation of the total points scored revealed that 64% were due to stroking errors, 32% due to outright stroking winners, and the remaining 4% due to service winners. Thus, almost two-thirds of all points won were a direct result of opponent's mistakes.

ANALYSIS OF STROKING ERRORS COMMITTED IN CHAMPIONSHIP TENNIS COMPETITION

by

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Abstract

The purpose of this study was to assess the stroking errors committed by collegiate tennis players in championship competition. Subjects in the study were participants in the 1978 NCAA Tennis Championships. Data were collected during direct observation of 36 tournament matches. The principle variable of interest, stroking error, was defined as any shot in which the ball failed to land within the prescribed court boundaries. This included shots that resulted in the ball going out of bounds or into the net, but did not distinguish between forced and unforced errors. Errors were classified relative to the position of the hitter (in the backcourt, midcourt, or at the net), as to whether a forehand or backhand was attempted, whether the ball was directed down-the-line (straight ahead) or crosscourt and as to the outcome of the stroke (the ball was either long, wide, long and wide, or hit into the net). In order to compare frequency of errors relative to the number of winners hit, comparable information was obtained on all tennis shots that resulted in an "outright winner" in which the opponent was not able to hit a return. Backhand down-the-line shots were the most predominant source of stroking error, while crosscourt forehands resulted in the fewest errors. Down-the-line shots produced over one and one-half times as many errors as crosscourt shots, yet yielded an equivalent number of outright winners. Analyses indicated that match winners hit 1.3 times as many winning shots as did match losers, while committing only 75% as many stroking errors. An evaluation of the total points scored revealed that 64% were due to stroking errors, 32% due to outright winners, and the remaining 4% due to service winners. Thus, almost two-thirds of all points won were a direct result of opponent's mistakes.

A fundamental skill required at any level of tennis competition is the ability to keep the ball in play. A beginner, for example, first learns to stroke the ball over the net to an awaiting opponent. Only after this skill is mastered does the novice attempt to hit the ball away from the opponent, yet within the prescribed court boundaries. Typical strategy, however, is to hit the ball over the net and into the court and let the other person make the mistake. Talbert and Old (4) focused on the importance of keeping the ball in play as they stated, "If required to pick the one most important factor in winning singles, we would unhesitatingly select keeping the ball in play. Errors are the killers in tennis." The concept of 'keeping the ball in play' is not limited to the beginning tennis player, however. Although not as obvious among professionals and tournament players, the inability to sustain the rally is the predominant cause of points being lost during a match. Tilmanis (5) emphasized this point as he stated, "Tennis matches are lost and not won" More points are won off errors than by winning placements." He further indicated that approximately 75% of all points scored in a tennis match are due to errors, three-fourths of which were the result of balls hitting the net. Van Horn (7) suggested that getting the ball over the net is a key strategy that is often neglected by teachers and coaches. He stated that even at the highest level of tennis, points were scored as a result of errors 75% of the time. He further stated that for beginners, errors outnumber placements at least 20 to 1. In a paper prepared by the Duke University Coaching Staff (2), it was suggested that 80% of all points earned in college tennis were due to opponents errors. Until the recent tennis boom and increased public interest in the sport, only the personal appraisal of a coach, teacher or sportswriter provided evidence to support such claims. The world-wide media coverage of tennis has enabled writers to compile an array of potentially useful empirical information. This information, however, is usually restricted to the role of trivia as it is used to supplement the account of a competitive match. Sigelschiffer (3) advocated that meaningful statistics should be included in tennis articles, such as it true for football, basketball or baseball. He provided a statistical summary of several key matches at the 1975 U. S. Open Championships to illustrate his point. The focus of Sigelschiffer's article appears to be toward the enhancement of the media coverage for the sophisticated tennis fan. However, the empirical information available from this statistical data should be carried one step further, for the findings have significant implications for both the teaching professional and the coach. Crookenden (1) and Tilmanis (5) both advocated charting matches in order to provide meaningful statistical information regarding a player's strengths and weaknesses. Van der Meer (6) provided match-play statistics of the 1976 U. S. Open Final between Connors and Borg to support his conclusion that more points are lost on errors than are won by outright winners. These are but a few of the professionals involved in a systematic means of improving tennis instruction and coaching. Too often, however, data collected may involve only a few individuals, or at best a tennis team, thereby restricting broader generalizations of pertinent findings.

The purpose of this study was to assess the stroking errors committed by collegiate tennis players in championship competition. Subjects in the study were participants in the 1978 NCAA Tennis Championships. Data were collected during direct observation of 36 tournament matches. The principle variable of interest, stroking error, was defined as any tennis shot in which the ball failed to land within the prescribed court boundaries. This included shots that resulted in the ball going out of bounds or into the net. The primary intent of the study was to focus on unforced errors; however, because of the subjectivity involved, an acceptable distinction between forced and unforced errors could not be easily established. Consequently, for the purpose of this study, no distinction was drawn between forced and unforced errors. Errors were classified relative to the position of the hitter (in the backcourt, midcourt area, or at the net); as to whether the ball was directed crosscourt or down-the-line (straight ahead); and as to the outcome of the stroke (the ball was either long, wide, long and wide, or hit into the net). In order to compare frequency of errors relative to the number of winners hit, comparable information was obtained on all shots that resulted in an "outright winner" in which the opponent was unable to hit a return shot towards the appropriate court. The data collection instrument is illustrated in Figure 1.

Backhand down-the-line shots were the most predominant source of stroking errors among the tournament participants surveyed. Crosscourt forehand shots, meanwhile, resulted in the fewest number of errors. Down-the-line shots, both forehand and backhand, produced over one and one-half times as many errors as did crosscourt shots, yet resulted in an equivalent number of outright winners. As expected, the forehand strokes proved to be the most reliable for virtually all performers, resulting in approximately 25% fewer errors than backhand strokes. A comparison of the proportion of crosscourt and down-the-line errors for both forehand and backhand is shown in Table 1.

Table 1. Proportion of Total Errors Relative to Shot-Type

	Crosscourt	Down-the-Line
Forehand	17.1%	24.7%
Backhand	21.8%	36.4%

Shots hit into the net accounted for over half (52%) of all the errors committed, while those going long or wide accounted for 29% and 19% respectively.

NAME:____________________________

Figure 1. Tennis Error Stroking Chart

	First Serve
IN	
OUT	
DOUBLE FAULTS	

		CROSSCOURT				STRAIGHT AHEAD			
		Long	Wide	Net	Winner	Long	Wide	Net	Winner
FOREHAND	Backcourt								
	Midcourt								
	Net								
BACKHAND	Backcourt								
	Midcourt								
	Net								

NAME:____________________________

	First Serve
IN	
OUT	
DOUBLE FAULTS	

		CROSSCOURT				STRAIGHT AHEAD			
		Long	Wide	Net	Winner	Long	Wide	Net	Winner
FOREHAND	Backcourt								
	Midcourt								
	Net								
BACKHAND	Backcourt								
	Midcourt								
	Net								

Figure 1.

For both forehand and backhand strokes, shots that were hit wide of the court boundaries accounted for the smallest porportion of stroking errors. In contrast, backhand down-the-line shots that were hit from the backcourt area produced the greatest number of stroking errors resulting in the ball being netted. Forehand and backhand strokes resulted in approximately the same number of errors in which the ball was hit long out of the court. The relative proportion of total errors committed classified as to error-type is illustrated in Table 2.

Table 2. Proportion of Total Errors by Error-Type

	Long	Wide	Net
Forehand	15.0%	6.9%	20.0%
Backhand	14.1%	11.7%	32.3%

Since the vast majority of all shots were played from near the baseline, it was not surprising that almost three-fourths of all errors were committed from the backcourt area. As indicated in Table 3, the backhand was particularly susceptible to this type of stroking error.

Table 3. Proportion of Total Errors Relative to Court Position

	Backcourt	Midcourt	Net
Forehand	28.0%	5.3%	8.5%
Backhand	45.4%	5.8%	7.0%

As previously indicated, forehand strokes were generally more reliable and, in fact, produced more outright winners than backhand strokes. Forehand down-the-line shots produced the greatest number of outright winners, almost 33% of all winners. It is shown in Table 4 that while down-the-line shots resulted in more forehand winners, crosscourt shots resulted in more backhand winners.

Table 4. Proportion of Outright Winners Relative to Shot-Type

	Crosscourt	Down-the-Line
Forehand	26.3%	31.6%
Backhand	23.9%	18.2%

In contrast to the high percentage of stroking errors made in the backcourt there was little difference in the proportion of winners hit from the backcourt or at the net, 40% and 36% respectively. In fact, forehand down-the-line shots hit while near the net accounted for the greatest number of outright winners. This finding suggests that a significant advantage may be gained by advancing to the net, thereby increasing the probability of being able to hit a winning shot. The relative proportion of outright winners classified as to where the shot was played is indicated in Table 5.

Table 5. Proportion of Outright Winners Relative to Court Position

	Backcourt	Midcourt	Net
Forehand	18.6%	9.4%	30.0%
Backhand	21.7%	4.3%	16.0%

An analysis of the total points won or lost through stroking opportunities indicated that there was little difference in the number of points associated with a forehand stroke and a backhand stroke. It is shown in Table 6 that backhand strokes accounted for 52.3% of the total points played in the matches surveyed (exclusive serve) and that forehand strokes accounted for 47.7% of the total points.

Table 6. Analysis of Total Points Won or Lost Through Stroking Opportunities

	Crosscourt		Down-the-Line		
	Errors	Winners	Errors	Winners	TOTAL
Forehand	10.9%	9.5%	15.7%	11.5%	47.7%
Backhand	13.9%	8.7%	23.2%	6.6%	52.3%

In regard to serving, it was found that tournament participants surveyed were able to hit 59.4% of their first serves into the proper service court. Match winners served slightly better than the losers, first serve efficiency being 61.4% as compared to 57.5% for the match losers. It was also determined that there was an average of two double faults per match, with no substantial difference between winners and losers.

Further analysis of the tournament data indicated that match winners hit 1.3 times as many winning shots as did match losers, while committing only three-fourths as many stroking errors. An evaluation of the total points scored revealed that 64% were due to stroking errors, 32% due to outright stroking winners, and the remaining 4% due to service winners. Thus, almost two-thirds of all points won were a direct result of opponents' mistakes.

While the aforementioned information was based on the composite data obtained on a number of players, statistics pertaining to only one player or to one match may be more useful to the tennis coach. Such statistical information may lead to the identification and diagnosis of a player's weaknesses or problem areas and may also provide scouting information on opponents. Table 7 contains a summary of pertinent statistics of the 1978 NCAA singles championship match. As the final score indicates, the match was extremely close with only two points difference at its conclusion, 144 points for McEnroe and 142 points for Sadri. Consequently, obvious differences in the match may be more difficult to ascertain even though it is apparent that Sadri served 21 more aces, but also committed 26 more stroking errors than McEnroe. Sadri's higher number of errors can be attributed to the fact that he was constantly attacking. A more striking example of a match in which statistical data clearly illustrates the determining factors is illustrated by the 1977 U.S. Open finals between Connors and Vilas (Table 8). Although only data relative to stroking errors were ascertained, it may be conjectured that Connors lost the match because of his preponderance of forehand down-the-line stroking errors.

The findings of this study provide empirical information that tends to support much of the subjective knowledge presently available regarding the sport of

Table 7. Statistical Summary of 1978 NCAA Singles Championship

MATCH STATISTICAL SUMMARY

94th NCAA SINGLES CHAMPIONSHIP

John McEnroe vs. John Sadri
May 29, 1978
Athens, Georgia

	McEnroe	Sadri
Total Errors Committed	61	87
Forehand	19	30
Backhand	42	57
Crosscourt	29	37
Straight Ahead	32	50
Hit from Backcourt	47	63
Hit from Midcourt	4	10
Hit from Net	10	14
Long	14	21
Wide	14	17
Net	30	48
Long & Wide	3	1
Double Faults	6	8
Total Outright Winners	46	51
Forehand	28	35
Backhand	18	16
Crosscourt	23	18
Straight Ahead	23	33
Hit from Backcourt	14	15
Hit from Midcourt	6	13
Hit from Net	26	23
Aces	3	24
% First Serves In	70%	56%

Match Score: McEnroe defeated Sadri 7-6 (5-3), 7-6 (5-3), 5-7, 7-6 (5-3)

Time of Match: 4 hours 15 minutes

Table 8. Statistical Summary of 1977 U.S. Open Finals

MATCH STATISTICAL SUMMARY

1977 U.S. OPEN SINGLES CHAMPIONSHIP

J. Connors vs. G. Vilas
Forest Hills, N.Y.

	Connors	Vilas
Total Errors Committed	90	72
Forehand	70	36
Backhand	20	36
Crosscourt	35	33
Straight Ahead	55	39
Hit from Backcourt	77	56
Hit from Midcourt	8	6
Hit from Net	5	10
Long	27	27
Wide	19	6
Net	2	5
Long & Wide	42	35

Match Score: Vilas defeated Connors 2-6, 6-3, 7-6, 6-0 tennis. The overall results of these analyses indicate that a systematic method of monitoring the stroking patterns of tennis players may provide valuable information to both the teaching professional and the tennis coach.

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REBOUND CHARACTERISTICS

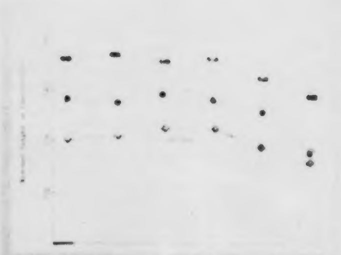
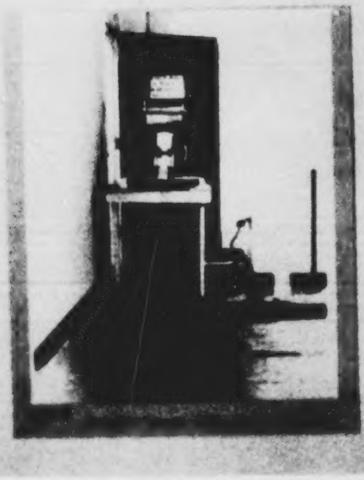
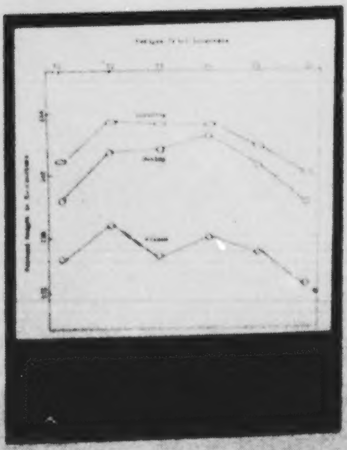


Fig 3

Rebound height averages for Spalding, Dunlop & Wilson control groups (cm)





A DYNAMIC TEST FOR COMPARISON OF REBOUND CHARACTERISTICS OF THREE BRANDS OF TENNIS BALLS

BY

Kenneth T. Rand, Jr.[2]

Michael W. Hyer[3]

Melvin H. Williams[4]

The purpose of this study was to compare Dunlop, Spalding, and Wilson pressurized tennis balls for rebound when fatigued at trial intervals of 0, 800, 1,600, 2,400, 3,200 and 4,000 bounce impacts. Eighteen yellow tennis balls, six each from Wilson, Dunlop and Spalding pressurized tennis cans were equally divided and randomly placed in a control or experimental group. The control group was not subjected to any fatigue. The experimental group was fatigued by use of a Lobster tennis ball firing machine. Both groups were filmed with a camera and strobe light assembly after each fatigue interval. The bounce height from a standardized drop was the criterion used which was determined by film analysis. The experiment was designed to indicate, with the use of a fatigue curve, which brand of balls fatigued the most and what number of bounce impacts were required to show fatigue.

Results of statistical analyses revealed that Spalding tennis balls rebound significantly higher than Wilson tennis balls, both when the balls were new and throughout the trials. The different brands of balls were found to fatigue at the same rate and time. It was also discovered that tennis balls may remain out of their pressurized can for 172.5 hours before there is a significant lowering in rebound height. The analyses revealed that an interaction occurred between trial one when the balls were new and trial two when the experimental balls had received 800 bounce impacts.

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In tennis there are many variables which effect the quality of play. This is true at all levels of tennis; professional, amateur and recreational. Many of these variables, such as grip, swing, strength, nimbleness and stamina are related to the physical ability of the individual players. Other variables, such as concentration, alertness and discipline are related to the mental ability of the player. However there are many variables which are related to the mechanical properties of the material in the equipment. The flexibility of the racket, the string material, the string tension, the weight of the racket, the abrasiveness of the court surface and of course the ball all affect play. Some contend that even shoes make a difference. Of course it is the difference in the mechanical properties and their relation to the game that is the basis for the manufacturer's claims for their products. For the professional athlete, much time is spent modifying and tuning equipment to get the best performance out of it. The amateur spends time at this as does the serious recreational player, since they generally do not have the time or mechanical aptitude to check the various advertising claims. It is difficult to determine what claims are valid and the latter two categories of players, as well as the average recreational player, are more-or-less at the mercy of the manufacturer's claims. However, some things are obvious. If, for example, a player is willing to commit substantial sums of money to the purchase of a tennis racket, one can be bought which is obviously lighter than the next one. However, when comparing two lightweight rackets, one does not know whether the flexural stiffnesses is different or whether one damps unwanted vibrations better. These comparisons involve testing beyond the capability of the average consumer if quantitative data are desired. But, the racquet is a major equipment purchase and, like the skies to the skier, some thought should go into the purchase.

The other major purchase, in terms of long-term investment, is balls. In 1975, balls accounted for 20% of the total amount of money spent for tennis by the consumer in the United States (1). There are many brands of tennis balls and within each brand, there are various types depending on whether the ball will be used on grass courts, clay courts or asphalt-based courts. Most tennis players, from the serious recreational level on up, acknowledge there is a difference in brands of tennis balls. Some of these differences are related to the flight characteristics of the ball while other differences relate to their ability to maintain constant characteristics throughout a game. While there may be differences, it is difficult to describe them in quantitative terms. Unlike the racquet, where flexibility, for example, is a clearly defined, measurable physical quantity, generally expressed as the amount of force to deflect the racquet a given amount, explaining differences between balls involves defining elastic and aerodynamic quantities. In addition, whatever component is being tested, there is always the problem of accurately stimulating the conditions the equipment actually experiences during use in a game with aerodynamics involved, this can be quite difficult. However, as a starting point, it was felt a meaningfulstudy would be to quantify the differences. This information would be useful to consumers, coaches, manufacturers, retailers, wholesalers and competitive players.

Scope of the Study

Since the characteristics of tennis balls involve both elastic and aerodynamic phenomena, the investigation could easily have become quite sophisticated, lengthy and expensive. To keep the investigation simple, and since it was a starting point, the scope of the study was limited. Basically the study was designed to test the rebound characteristics of several brands of tennis balls as a function of the number of times the balls impacted a hard surface. The philosophy behind this was that the repeated impacting of the ball on the playing surface and the rackets was the major cause of the change in the characteristics of the ball. Exactly what characteristics were changed and in what manner they changed was really the question but the general feeling was that the tendency to rebound from a hard surface, the so-called resiliency, was effected by the repeated impacting during a game. At first thought, one would suspect that changes in the elastic properties of the ball material and changes in the internal pressure would be important sources of change in the rebound characteristics with repeated impacting. Secondary effects might be the loss of mass due to the loss of nap from the new-ball condition as the ball was subjected to usage. Also related to the mass are other secondary effects which might be associated with the excessive scraping-off of nap or even rubber in localized areas due to the spinning ball hitting the abrasive court surface. This would cause an unsymmetric mass distribution for the ball but over the long-term, this localized abrading probably is distributed uniformly over the ball and merely contributes to an overall loss of material from the ball. Since aerodynamic effects are quite important to the performance of tennis balls, they have to be considered. However, aerodynamic testing was felt to be beyond the scope of this initial test and so its effects would be lumped into the sum of all other effects when measuring rebound. In short, it was felt the measure of tennis ball rebound ability would measure the changes in the important variables effecting tennis ball performance.

Methodology

The rebound ability was measured by dropping the balls vertically, in the air, from a certain height and measuring the rebound height after they rebounded from a hard horizontal surface. The testing proceeded as follows: The balls were removed from their cans, their rebound heights, when new, were measured. The balls were then subjected to repeated impacts on a hard surface for a certain number of impacts. The rebound heights were again measured. The balls were then subjected to another series of impacts and the rebound measurements repeated. This impacting - rebound measuring procedure was repeated for five cycles. The rebound height was recorded with a strobe and camera set-up using a calibrated vertical scale behind the rebound path to measure height.

A total of 18 balls were used, six each from three different manufacturers. The balls were purchased on the same day and from different retailers. No attempt was made to determine the exact manufacturing date for the balls. All brands indicated on the container the balls were specifically designed for play on all hard-court surface. As a control group, half of the balls in each brand were set aside and were not subjected to the repeated impacting. However, their rebound characteristics were measured at the same times the impacted, or experimental group were measured, that is, after each series of impact tests. Thus, with the control group, there would be a measure of the effect of strictly out-of-can time on rebound characteristics. The process of impacting and filming the rebound took a substantial amount of time... about eight hours per cycle. Thus the tests were spread over a week's time, one series of impacts per day. To account for time effects between the end of rebound height measurements after one series of impacts and the beginning of the next series of impacts, essentially overnight, the rebound heights were recorded prior to the start of the next series of impacts. Thus the balls were impacted, their rebound heights measured, left overnight, rebound heights measured again and then impacting resumed. Just before the first filming and impacting cycle began, the balls were removed from their cans, weighed and numbered with a marker so individual balls could be tagged if necessary.

To impact the balls on a hard surface, a tennis-ball firing machine was used to propel the balls. The particular machine used propelled the balls pneumatically. The balls were fired onto a portable tennis court surface which was laid down on a smooth concrete floor. All testing was done indoors. The balls impacted the court surface at about 20°, as measured from the horizontal, after having traveled a downward-angle distance of about 5.5 meters after leaving the firing machine. To increase the number of impacts per firing of the machine and to aid on retrieval of the tennis balls during the testing, the testing was done toward a vertical wall and after bouncing from the floor, the ball traveled another five meters and hit the wall. The wall, which was cinder-block, was also covered with the tennis court surface. Thus the ball impacted twice though the second bounce was of reduced intensity. After the balls were retrieved from firing, they were loaded into the ball firing machine, in no particular order, and fired again. This procedure was repeated for 400 times for all nine balls in the experimental group. After a series of 400 firings, the rebound height of each ball was measured.

To measure the rebound height, the balls were dropped from a height of 227 centimeters onto a smooth, painted concrete floor. Shortly after dropping the ball and hitting the floor, the camera shutter was opened manually and the subsequent upward travel of the ball recorded on film in step-wise fashion using the strobe to illuminate the ball. The shutter was closed shortly after the ball started downward again. A vacuum system was used to hold and then release the ball from its initial height. An inverted circular funnel, a little larger in diameter than the tennis ball, was mounted on a bracket about 4 cm. from a vertical wall. The end of the funnel was connected, by way of a flexible neoprene tubing, to a vacuum pump. With the pump on, the ball was held in position within the funnel. When the vacuum was turned off, the ball dropped from the funnel. This mechanism was used since it was rather simple and, since the ball was held uniformly around its circumference, the system imparted no initial motion, such as spin, to the ball during release,(something a mechanical system might do). A vertical scale was mounted on the wall behind the ball, a distance of about 4 cm. to measure the rebound height. The camera, single-lens reflex, was mounted on a tripod with the center of the lens 5 meters, horizontally, from the ball drop apparatus and about 1.5 meters above the floor. The strobe light was placed on the floor, facing the ball, between the cameras and the ball-drop. Pilot tests with the set-up indicated the best combination of strobe rate and lens opening. After the rebounds were photographed, the film was developed and the negatives were viewed through a commonly available device which enlarged the 35 mm negative image. With this, the rebound distance up the vertical scale could be easily determined. Each ball was dropped twice for any particular rebound measurement and the average of the two bounces used. In general, the two bounces were quite close although occasionally there was a spurious bounce of the ball. If a spurious bounce occurred, only the one rebound measurement was used. Even though the lens diameter was smaller than the diameter of the tennis ball, parallax error was minimized by the five meter distance from lens to ball. All testing was done indoors. Further details of the test set-up, the test equipment, lens openings, strobe rates and film types are available (Rand, 1976).

Results

Figure 1 depicts the plot of rebound height vs. the number of impacts for the experimental group of balls. The initial height was 227 centimeters and recall that for a given number of impacts; half of these were of lesser intensity. Each data point on the plot generally represents the average of six measurements, three balls per brand and two rebound measurements per ball. Since the measurements were done by visually interpreting an enlarged image of the negative, a test was conducted to determine the ability to consistently read film. The individual reading the negatives was repeatedly given a series of negatives to interpret, each time in a random order and a correlation coefficient of .99 was established for consistency in reading the negatives.

All three brands rebounded higher after 800 impacts than when they were just out of the can. This trend was observed for all balls and is attributed to a decrease in aerodynamic drag associated with the loss of nap from the new-ball condition. It is well known, for example, that quantities of nap come off new balls and indoor courts must be cleaned periodically to remove this loose nap from the playing area. Some of this loss of nap is due to the excess nap that is on the surface of the ball from the manufacturing process but some of the loss of nap is due to the surface of the new ball gradually wearing away with use. The ball surface on some balls tends to smooth out with the nap loss and the aerodynamic drag decreases, resulting in a livelier ball. Of the three brands, brand A bounced the highest when new; also throughout the series of tests. On the other hand, brand C consistently bounced lowest. The sudden dip in the performance of brand B cannot be explained. In general, the performance of the balls was better than

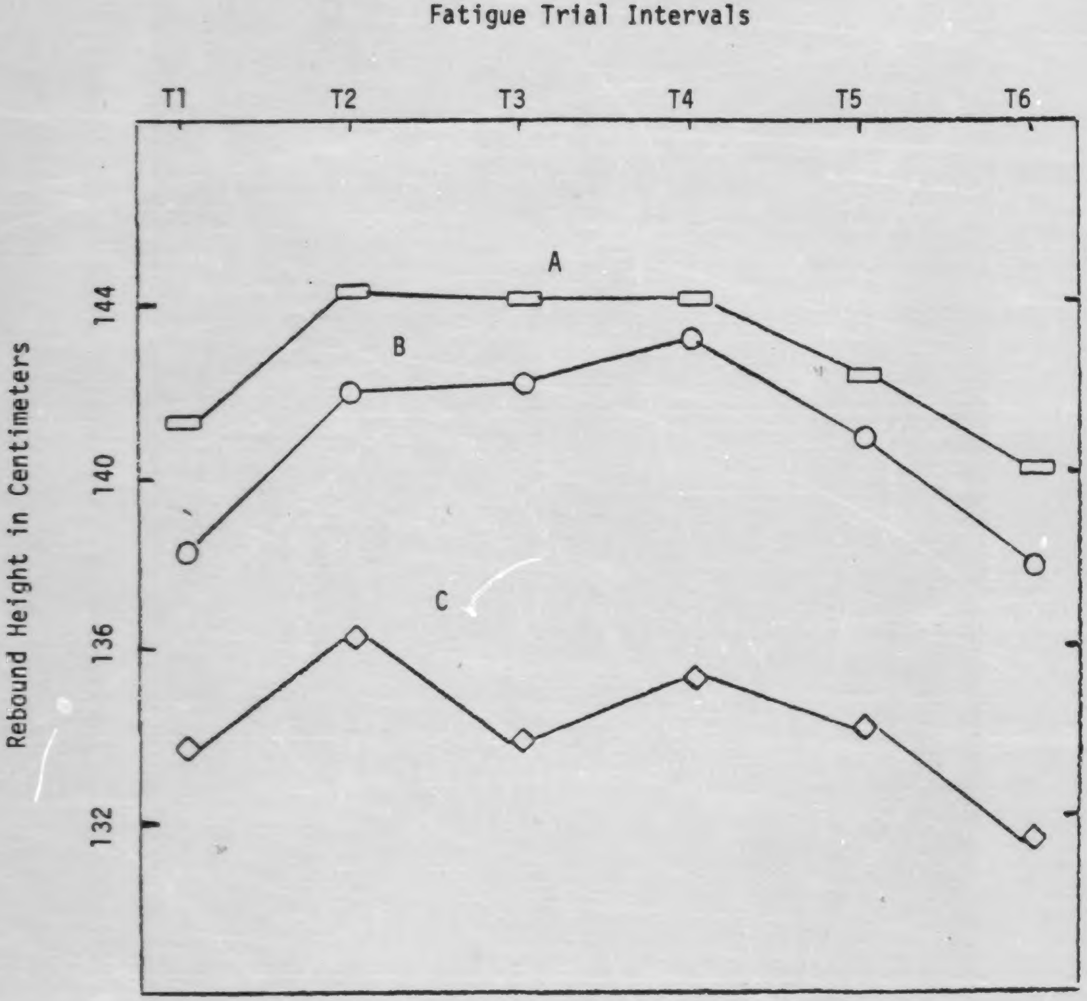

Figure 1. Rebound height averages for Spalding, Dunlop and Wilson experimental groups (n=3)

the new-ball condition up to 3200 impacts. After that, the ball's performance deteriorated rapidly and the balls began to behave worse than at the new-ball state. With this testing procedure, the balls had been out of the can 7.14 days before they began to show significant deterioration from the reduced drag condition. Figure 2 depicts the rebound characteristics of the control group. Each data point is also generally the average of six measurements and the figure shows the performance of the balls as fairly constant until they had been out of the can for five days. Since the balls were not being used, their nap cover remained the same as when new and thus, the aerodynamic characteristics remained constant with time. With the control group, as with the experimental group, brand A consistently rebounded the highest while brand C rebounded the lowest.

Apparently out-of-can time was a major factor affecting the rebound performance. The experimental group's performance improved with the loss of nap and remained fairly consistent up to five days. After that time, both groups' performance deteriorated, indicating the strong effect of out-of-can time.

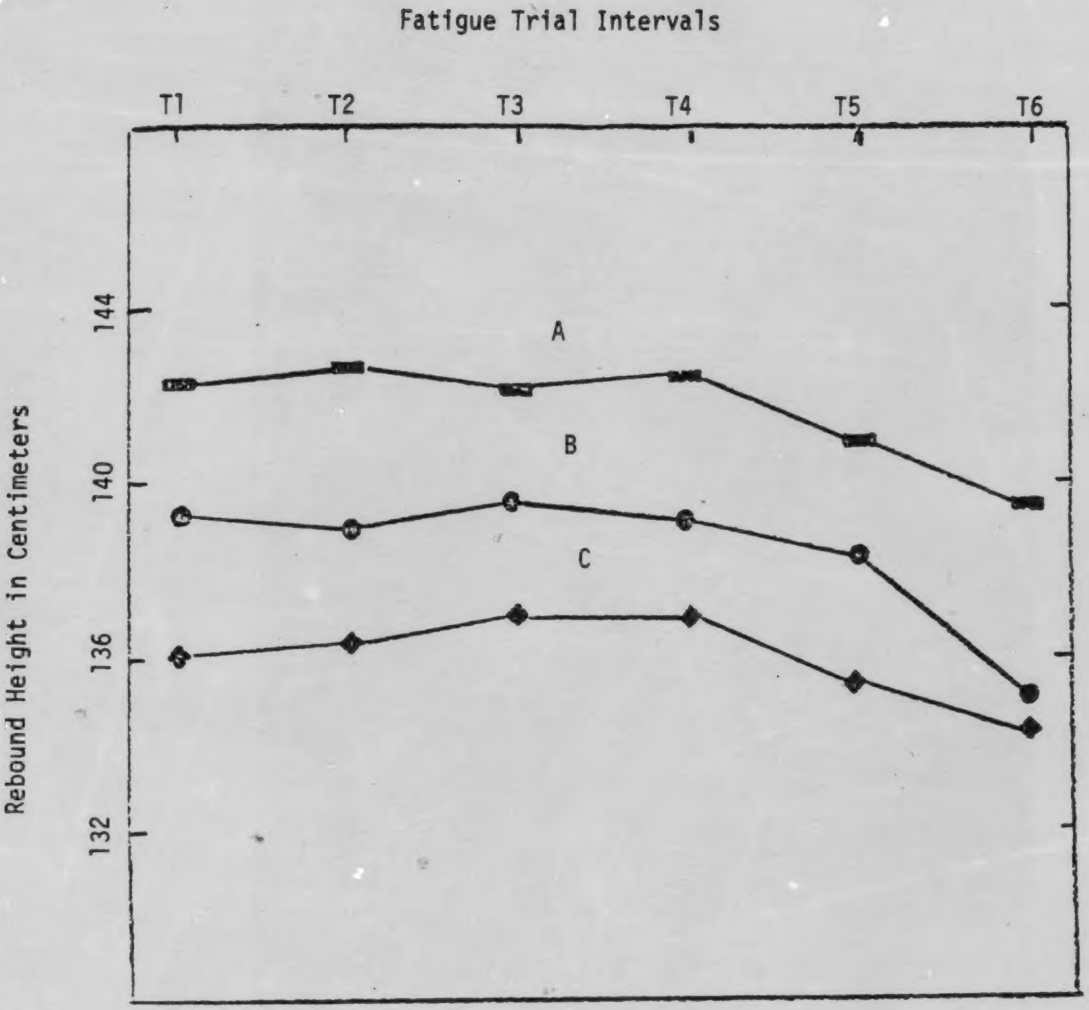

Figure 2. Rebound height averages for Spalding, Dunlop and Wilson control groups (n=3)

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A Cinematographic Analysis of the Tennis One-Handed Backhand Drive as Used by Skilled and Unskilled Female Performers

by

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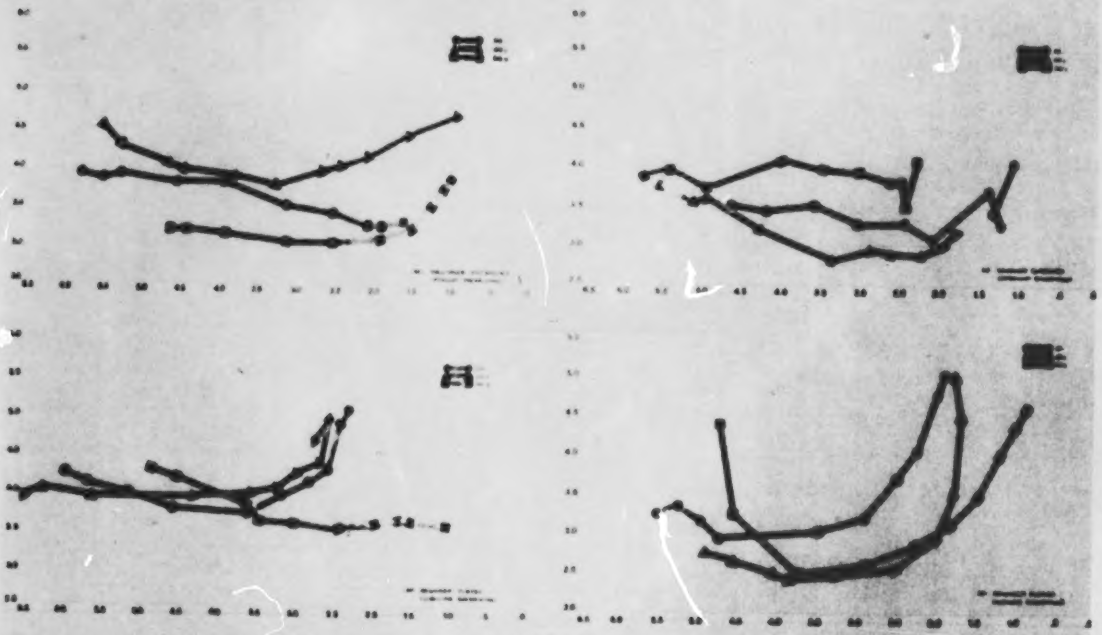

Graph Units in Feet

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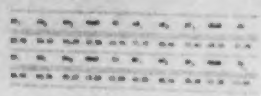

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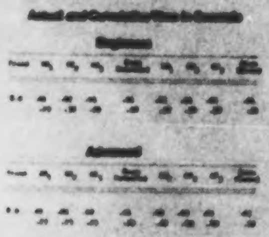

Conclusion

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A CINEMATOGRAPHIC ANALYSIS OF THE TENNIS ONE-HANDED BACKHAND DRIVE AS USED BY SKILLED AND UNSKILLED PERFORMERS

by

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Abstract

The purpose of this study was to analyze and compare the performance techniques of beginning and advanced female tennis players while utilizing the one-handed backhand drive. The subjects selected were six college varsity competitors and six beginning tennis players.

The subjects were filmed at 100 frames per second while executing the ground stroke. The following parameters were described: the elbow angle at the start of the forward swing through the contact point; racket head linear displacement; linear velocity of the racket; actual and cumulative time from the completion of the backswing through the contact point; and the position of ball impact with respect to the body.

The following were concluded: (1) subjects using a circular backswing averaged the greatest increase at the elbow angle and had higher racket head velocities at impact than those subjects using a straight backswing; (2) the subjects using a straight backswing averaged the greatest racket head velocity from the beginning of the forward swing through ball impact than the subjects using the circular backswing; and (3) the unskilled subjects were more inconsistent with body positioning with respect to the ball than the skilled subjects, often resulting in lower racket head velocities prior to ball contact.

Although a great deal of information exists concerning the one-handed backhand drive, a true scientific foundation is lacking. In recent years biomechanical principles have been employed in the analysis of various athletic skills including tennis fundamentals. In order to provide sound tennis instruction for all abilities, tennis fundamentals must be completely analyzed so individuals can acquire effective and mechanically efficient fundamentals. A review of the literature on tennis yielded a minimal amount of material in which investigators have analyzed the one-handed backhand biomechanically. (Broer, 1973; Groppel, 1978; Braden and Bruns, 1977; Roswal, 1974; Holcomb, 1963; Plagenhoef, 1970). Thus, a study analyzing and comparing the performance techniques of beginning and advanced female tennis players while utilizing the one-handed backhand drive was conducted at the University of Wisconsin - LaCrosse in 1978.

It is the purpose of this paper to present:

1) a selected review of related literature;

2) the parameters described in the study:

   a) flexion of the elbow joint;
   b) racket head linear displacement;
   c) linear velocity of the racket (fps)
   d) actual and cumulative time from the completion of the backswing through the contact point; and
   e) position of ball impact with respect to the body

3) the conclusions warranted by this investigation.

Review of Related Literature

Numerous articles have been written describing the basics of the one-handed backhand. Most of the information available has been written by playing professionals, teaching professionals and authorities of the game. The literature concerning the one-handed backhand is usually opinionated, subjective and varied from author to author; thus, lacking a scientific foundation. According to Murphy (1977), knowledge of mechanical principles resulted in more success for the average tennis player.

Various techniques have been advocated in the presentation of the one-handed backhand groundstroke. Inconsistencies exist in the opinions of investigators as to what degree the elbow should be flexed at the completion of the backswing. For example, the degree of flexion in the elbow joint reported in the literature ranged from bringing the racket back in a circular motion with the racket head shoulder level to bringing the racket straight back with the racket head located in the hip region. According to Braden and Bruns (1977) all good strokes are supported by sound physical laws which dictate the action of the racket, its impact on the ball and the movement of the body. Players applying the physical laws to the performance of the one-handed backhand can produce identical results on shots by hitting the ball exactly the same way.

Strength, speed of movement, flexibility, reaction time, power, and hand-eye coordination are also factors which could affect the performance of the one-handed backhand (Broer, 1973). Murphy (1977) indicated that there are differences in physique, temperment, and personality and that strokes should be adapted to the individual's needs and abilities.

Because of the minimal amount of biomechanical research available on the one-handed backhand groundstroke and the conflicting views of the already existing research, there is a need in the tennis area to further develop this knowledge.

The biomechanical data for the subjects in this study are presented in the following sections: (1) flexion of the elbow joint; (2) racket head linear displacement; (3) linear velocity of the racket (fps); (4) actual and cumulative time from the completion of the backswing through the contact point; and (5) position of ball impact with respect to body.

Flexion of the Elbow Joint. To determine if a player had a flexed or an extended elbow at the completion of the backswing, the following criteria were established prior to the selection of the subjects: a flexed elbow, 0° - 130°; and an extended elbow, 131° - 180°. Only beginning and advanced players were used in this study. Hereafter, an advanced player who used a straight backswing, which indicates an extended elbow, will be identified as AE; an advanced player who used a circular backswing, which indicates a flexed elbow, will be identified as AF; a beginning player who used a straight backswing, which indicates an extended elbow, will be identified as BE; and a beginning player who used a circular backswing, which indicates a flexed elbow, will be identified as BF.

The flexion of the elbow joint at each frame, one through ten, for each of the subjects are presented in Table 1. As would be expected, the AF and the BF subjects averaged the greatest increase in the angle of the elbow joint.

Racket Head Linear Displacement. Figure 1 represents the linear displacement of the center of gravity (COG) of the racket for frames 1-9 for the advanced subjects and Figure 2 depicts this same displacement for the beginning subjects.

Actual and Cumulative Time. The actual and cumulative time from the completion of the backswing through the contact point are presented in Table 2 for the advanced subjects and in Table 3 for the beginning subjects. The flexed were expected to travel a further distance due to the circular backswing. If the racket travels a longer distance in a shorter period of time, there should be greater velocity of the racket at impact. Broer (1973) indicated that a circular backswing added considerable time availability for the development of the momentum of the racket, but at the same time, increased the difficulty of timing the stroke and controlling the angle of the hit.

Linear Velocity of the Racket (fps). Table 4 indicates the linear velocity of the racket at impact (frame 9).

Table 1

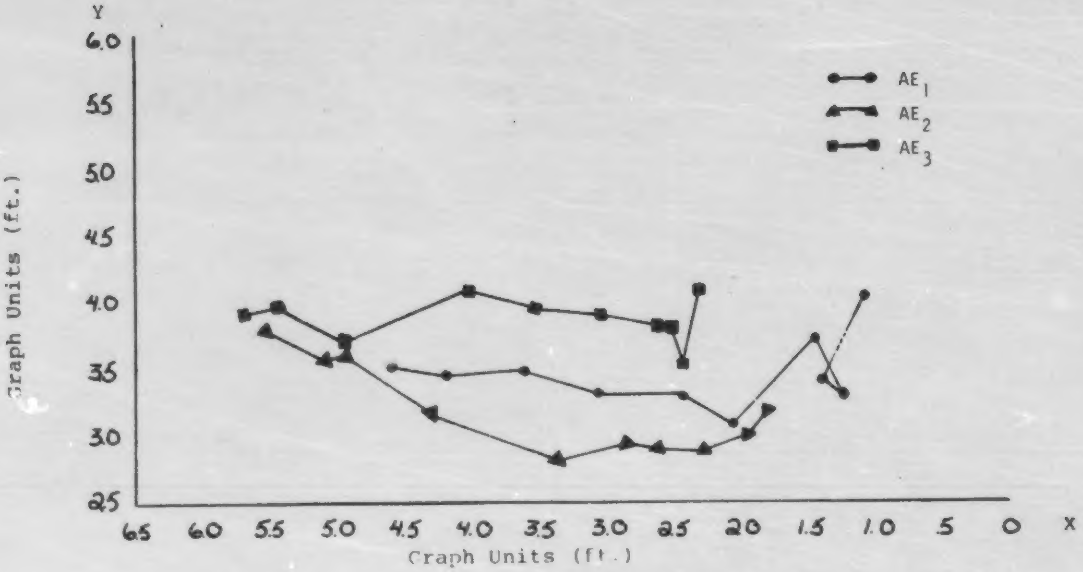
Elbow Joint Flexion (Degrees)

Advanced

FRAME	AE_1	AE_2	AE_3	Mean Extended	SD	AF_1	AF_2	AF_3	Mean Flexed	SD
1	156.21	131.56	161.96	149.91	16.14	102.73	97.98	90.79	90.79	6.01
2	159.05	129.89	147.90	145.61	14.71	115.40	103.88	116.25	111.84	6.90
3	156.60	119.77	144.42	140.26	18.52	127.69	110.00	132.80	123.50	11.96
4	150.49	120.98	160.68	145.49	21.44	129.91	122.83	149.98	134.24	14.08
5	166.05	122.75	147.90	145.57	21.74	144.66	124.19	168.77	145.87	22.31
6	172.51	148.50	178.91	166.64	16.03	179.37	146.19	176.93	167.50	18.49
7	177.10	179.16	178.32	178.19	1.03	143.81	166.47	177.71	162.66	17.26
8	174.92	155.09	178.76	169.59	12.70	172.07	171.48	170.49	171.35	.79
9	174.10	161.37	162.52	166.00	7.04	173.71	154.55	167.88	165.38	9.82
10	168.92	159.51	169.18	165.87	5.50	166.63	170.00	166.95	167.87	1.86
MEAN	166.03	142.86	163.06	157.31		145.60	136.76	151.86	144.74	
SD	8.66	20.63	13.25	6.93		26.65	28.38	29.39	7.18	

Beginners

FRAME	BE_1	BE_2	BE_3	Mean Extended	SD	BF_1	BF_2	BF_3	Mean Flexed	SD
1	151.86	149.83	138.65	146.78	7.11	109.65	121.58	110.65	113.96	6.61
2	149.55	129.58	135.51	138.21	10.25	114.84	117.99	106.19	113.01	6.10
3	138.09	119.44	132.79	130.11	9.61	116.48	110.70	102.68	109.95	6.93
4	140.37	101.10	126.18	122.55	19.88	111.98	110.02	95.08	105.69	9.24
5	143.63	108.35	125.33	125.77	17.64	106.04	108.62	100.77	105.14	4.00
6	149.34	153.69	127.13	143.39	14.24	114.43	133.60	92.52	114.52	19.04
7	144.46	176.37	136.73	152.53	21.00	135.99	174.70	100.06	136.92	37.32
8	171.33	173.73	166.15	170.40	3.87	147.47	168.48	120.32	145.42	24.14
9	173.51	163.35	178.31	171.72	7.63	173.66	158.62	172.61	168.30	8.39
10	170.50	157.33	173.98	167.27	8.78	179.05	166.58	166.26	170.63	7.29
MEAN	153.27	143.28	144.08	146.87		130.96	137.09	117.01	128.35	
SD	13.46	26.93	20.53	5.85		27.10	27.06	28.64	10.67	



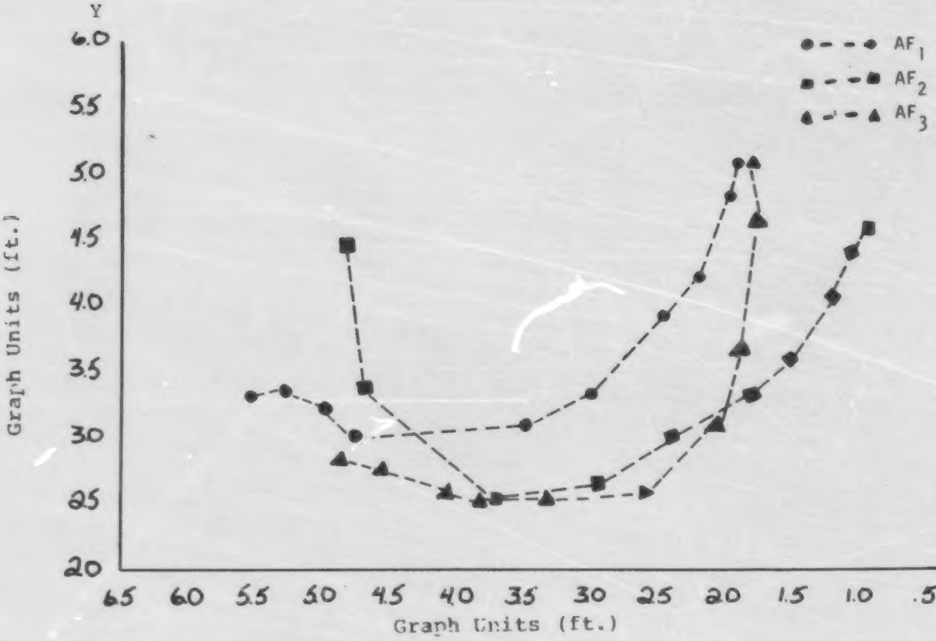


Figure 1. Linear displacement of racket COG for advanced subjects.

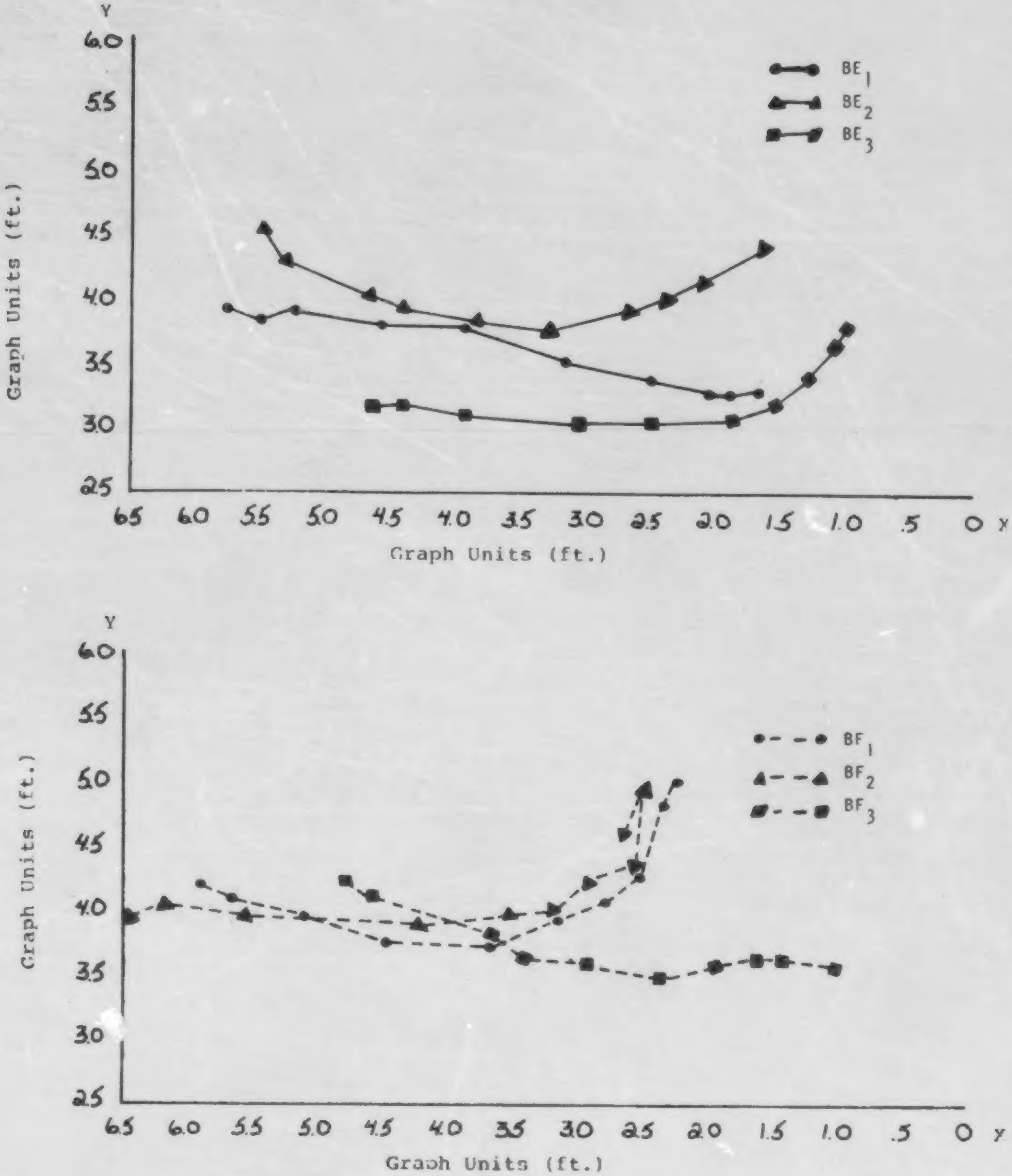


Figure 2. Linear displacement of racket COG for beginning subjects.

Table 2

Actual and Cumulative Time (seconds)

Advanced

Frame	AE_1	AE_2	AE_3	Mean Extended	AF_1	AF_2	AF_3	Mean Flexed
1-2	.06	.05	.06	.06	.07	.05	.20	.11
2-3	.03	.05	.07	.05	.06	.05	.10	.07
	.09	.10	.13	.11	.13	.10	.30	.14
3-4	.04	.03	.03	.03	.03	.05	.05	.04
	.13	.13	.16	.14	.16	.15	.35	.22
4-5	.03	.02	.03	.03	.05	.03	.05	.04
	.16	.15	.19	.16	.21	.18	.40	.26
5-6	.02	.02	.02	.02	.03	.04	.03	.03
	.18	.17	.21	.18	.24	.22	.43	.30
6-7	.02	.02	.01	.02	.02	.03	.02	.02
	.20	.19	.22	.20	.26	.25	.45	.32
7-8	.02	.03	.01	.02	.02	.02	.03	.02
	.22	.22	.23	.22	.28	.27	.48	.34
8-9	.01	.01	.02	.01	.01	.02	.01	.01
	.23	.23	.25	.23	.29	.29	.49	.35
9-10	.01	.01	.01	.01	.01	.01	.01	.01
	.24	.24	.26	.24	.30	.30	.50	.36
MEAN	.03	.03	.03	.01	.03	.03	.06	.04
	.17	.16	.19	.17	.22	.22	.40	.27
SD	.02	.02	.02	.02	.02	.02	.06	.03
	.06	.06	.06	.06	.08	.09	.10	.09

Table 3

Actual and Cumulative Time (seconds)

Beginners

Frame	BE_1	BE_2	BE_3	Mean Extended	BF_1	BF_2	BF_3	Mean Flexed
1-2	.08	.05	.07	.07	.05	.08	.10	.06
2-3	.02 .10	.08 .13	.05 .12	.05 .12	.10 .15	.05 .13	.03 .13	.06 .14
3-4	.02 .12	.05 .18	.05 .17	.04 .16	.05 .20	.05 .18	.03 .16	.04 .15
4-5	.03 .15	.02 .20	.05 .22	.03 .19	.03 .23	.05 .23	.03 .19	.04 .18
5-6	.02 .17	.04 .24	.03 .25	.03 .22	.03 .26	.03 .26	.03 .22	.03 .25
6-7	.03 .20	.03 .27	.02 .27	.03 .25	.03 .29	.03 .29	.02 .24	.03 .27
7-8	.02 .22	.03 .30	.01 .28	.02 .27	.02 .31	.04 .33	.02 .26	.03 .30
8-9	.01 .23	.02 .32	.01 .29	.01 .28	.01 .32	.01 .34	.02 .28	.01 .31
9-10	.01 .24	.01 .33	.01 .30	.01 .29	.01 .33	.01 .35	.01 .29	.01 .32
MEAN	.03 .17	.04 .22	.03 .23	.02 .21	.04 .24	.04 .24	.02 .21	.04 .22
SD	.02 .06	.02 .09	.02 .06	.10 .08	.02 .09	.02 .10	.10 .07	.02 .09

Table 4

Linear Velocity of the Racket (fps)

AE_1	AE_2	AE_3	MEAN	SD	AF_1	AF_2	AF_3	MEAN	SD
52.01	23.19	26.63	33.94	15.74	31.22	65.64	51.62	49.53	17.26

BE_1	BE_2	BE_3	MEAN	SD	BF_1	BF_2	BF_3	MEAN	SD
30.41	68.96	29.27	42.88	22.59	58.52	32.16	39.22	43.30	13.65

The AE & BE averaged the greatest linear velocity between frames 7-8, which was prior to impact. On the other hand, the AF and BF averaged the greatest linear velocity at impact, which was between frames 8-9. It was also noted that the AF had a gradual increase in the velocity of the racket from the completion of the backswing through the contact point. The BF also showed a gradual increase in the velocity of the racket although a decrease of .79 fps was noted in frames 3-4. The AE showed a decreased from frames 2-4 with a gradual increase in the velocity of the racket until contact. Immediately after impact, the beginning subjects decreased the velocity of the racket, while the advanced subjects experienced an increase. This difference between the groups may be explained by the fact that the advanced subjects held a firm wrist at contact and that ball contact was made in the center of the strings, which caused less vibration to be transmitted to the hand.

Position of Ball Impact with Respect to the Body. According to Roswal (1974) the ball should be contacted perpendicularly above the placement of the front foot or slightly ahead of it. By contacting the ball ahead of the front foot and in the hip region a player should be able to produce the maximum power in the stroke.

Three beginning subjects had a tendency to start the forward swing with the elbow leading, causing them to contact the ball higher. The beginning subjects were more inconsistent in the positioning of the body in relation to the ball than the advanced subjects. The beginning subjects did not step into the ball and enlarge the base in the direction of the force to allow a decided shift of the COG. They positioned themselves too close or too far behind the bounce of the ball to step into the ball properly.

Both the beginning and the advanced subjects contacted the ball ahead of the front foot which should have enabled them to get maximum power into the ball. Not all subjects did as the body weight appeared to move backward or to the left of the subjects prior to impact of the ball. This was caused by improper positioning of the body in relation to the ball. The beginners did not keep their knees flexed during the contact of the ball which would cause the body to be off balance with the end result being less force transmitted to the ball at impact.

Conclusions

The following were concluded: (1) subjects using a circular backswing averaged the greatest increase at the elbow angle and had higher racket head velocities at impact than those subjects using a straight backswing; (2) the subjects using a straight backswing averaged the greatest racket head velocity from the beginning of the forward swing through ball impact than the individuals using the circular backswing; and (3) the unskilled subjects were more inconsistent with body positioning with respect to the ball than the skilled subjects, often resulting in lower racket head velocities prior to ball contact.

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USE OF A CONTINUOUS STEP TRAINING PROGRAM IN BUILDING CARDIOVASCULAR FITNESS FOR A COLLEGE TENNIS TEAM

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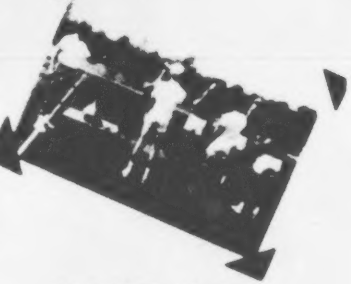
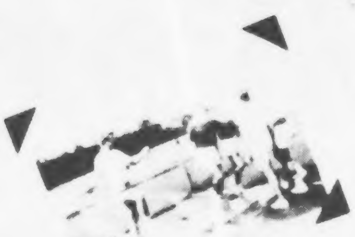
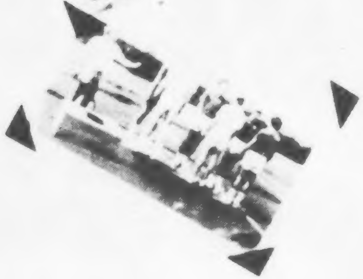
[illegible]

[illegible] minutes each, followed by a one minute recovery phase for rest. The stepping is done at a fixed cadence of 140 beats per minute.

The continuous step training program is adaptable for use in evaluation as well as in training. Tennis team members participating in the program show improved cardiovascular fitness and increased leg strength, both important prerequisites for competitive tennis. The program requires only a little over ten minutes a day to carry out, and the steps are economical to construct. In short, participating in the continuous step training program provides tennis players with maximum fitness benefits for a minimum investment of time and equipment.

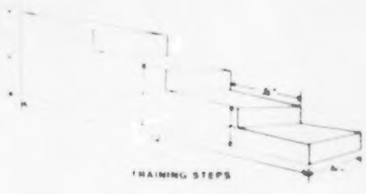




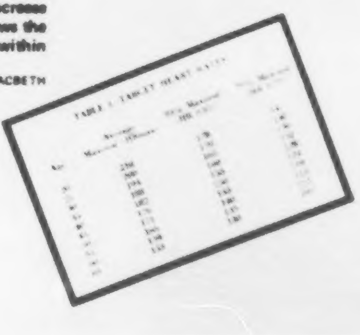


[illegible] of carrying out the study, the investigators made several observations [illegible] of step training in general. First, step training is practical for mass [illegible] college tennis team situation. It requires little special equipment and can [illegible] easily. Second, step training has the advantage of not requiring the [illegible] exert maximal effort or possess a high degree of skill. The gradual increase [illegible] energy of the continuous type of step training used in this study allows the [illegible] system sufficient time to adapt so that the individual is working within [illegible] physiologic limitations at all times.

AUTHORS: DICK LALANCE, JON MACBETH



TRAINING STEPS



USE OF A CONTINUOUS STEP TRAINING PROGRAM IN BUILDING CARDIOVASCULAR FITNESS FOR A COLLEGE TENNIS TEAM

by

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Abstract

A continuous step training program is used as part of the conditioning program for the Middle Tennessee State University tennis team and has been found to have significant benefits for improving cardiovascular fitness and work capacity and for developing leg strength. The program requires little equipment and only a brief segment of time each day at the beginning or end of the training session. Using a set of steps of graduated heights designed by Dr. George V. Mann of the Vanderbilt School of Medicine and Dr. Leon Garrett of the University of Kentucky, the program consists of three phases -- warm-up, workout, and recovery. After a brief warm-up period, tennis team members are asked to step at four, eight, and twelve inch levels for three minutes each, followed by a one minute recovery phase for rest. The stepping is done at a fixed cadence of 140 beats per minute.

The continuous step training program is adaptable for use in evaluation as well as in training. Tennis team members participating in the program show improved cardiovascular fitness and increased leg strength, both important prerequisites for competitive tennis. The program requires only a little over ten minutes a day to carry out, and the steps are economical to construct. In short, participating in the continuous step training program provides tennis players with maximum fitness benefits for a minimum investment of time and equipment.

In the past few years many different kinds of exercise programs have been designed to improve physical fitness, in particular, cardiovascular fitness. It has been shown that an individual with an efficient cardiovascular system can sustain work longer, has a slower resting pulse rate and lower blood pressure, is able to increase his maximal oxygen consumption and is less prone to fatigue. In this study the investigators sought to determine what effects, if any, a continuous step training program would have on the cardiovascular fitness of members of a college tennis team.

A continuous step training program was defined as a program of training designed to increase workload progressively following a warm-up period of light work; the workload could be continued to exhaustive levels or it could be stopped at some predetermined point.

PROCEDURES

Varsity tennis team members at Middle Tennessee State University were selected to provide subjects for the study. A total of 8 members, aged 19 to 22 years, agreed to participate.

Using a set of steps of graduated heights designed by Dr. George V. Mann of the Vanderbilt School of Medicine and Dr. Leon Garrett of the Universty of Kentucky, the program consists of three phases -- warm-up, workout, and recovery. After a brief warm-up period, tennis team members are asked to stop at four, eight, and twelve inch levels for three minutes each, followed by a one minute recovery phase for rest. The stepping is done at a fixed cadence of 140 beats per minute.

In the continuous step training program certain controls were employed to make each session as nearly alike as possible. The cadence was pre-recorded on a cassette tape recorder to ensure correct timing and the tape was properly calibrated. During the recovery phase of each session, a 15 second pulse for each subject was taken using either the left radial or left carotid artery.

OBSERVATIONS

In the process of carrying out the study, the investigators made several observations about the use of step training in general. First, step training is practical for mass training in a college tennis team situation. It requires little special equipment and can be administered easily. Second, step training has the advantage of not requiring the subject to exert maximal effort or possess a high degree of skill. The gradual increase demand for energy of the continuous type of step training used in this study allows the cardiovascular system sufficient time to adapt so that the individual is working within his physiologic limitations at all times.

SUMMARY AND IMPLICATIONS

A continuous step training program is used as part of the conditioning program for the Middle Tennessee State University tennis team and has been found to have significant benefits for improving cardiovascular fitness and work capacity and for developing leg strength. The program requires little equipment and only a brief segment of time each day at the beginning or end of the training session.

The continuous step training program is adaptable for use in evaluation as well as in training. Tennis team members participating in the program show improved cardiovascular fitness and increased leg strength, both important prerequisites for competitive tennis. The program requires only a little over ten minutes a day to carry out, and the steps are economical to construct. In short, participating in the continuous step training program provides tennis players with maximum fitness benefits for a minimum investment of time and equipment.

INVITED PRESENTATIONS

OCULAR INJURIES IN RACQUET SPORTS

by

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Abstract

Severe injury to the eye can occur during racquet sports participation. There are primarily two varieties of severe eye injury seen:

1. Fractures
    a) Orbital rim (rare)
    b) "Blow-out" fractures of orbit (common)
2. Intra-ocular damage
    a) Rupture of globe--A classic and fascinating case presentation with video-taped surgical repair will be presented. A 70 year-old tennis player underwent successful extracapsular cataract surgery with capsular fixation intraocular lens implantation. His resultant visual acuity was better than 20/20. He was hit directly in the eye with iris prolapse approximately 10mm in length. Surgical repair was performed immediately. Despite the severity of the injury, his visual acuity two months after injury returned to 20/20
    b) Intra-ocular hemorrhage
    c) Retinal scarring ("commotio retinae")
    d) Retinal detachment
    e) Late sequelae--chamber angle deformity with glaucoma

The means of preventing these injuries are:

1. Education regarding potential hazards
2. Training in the sport
3. Use of protective eye wear

Although severe eye injuries are statistically unusual in the racquet sports, the injuries sustained are vision threatening. A unique videotape of such an injury and repair is presented.

Severe injuries to the eye and surrounding structures can occur from participation in the racquet sports. Such injuries can be caused either by the racquet, the ball, physical collision, or breakage of contact lenses or glasses. Lid, skin, brow lacerations, subcutaneous ecchymosis (black eyes), and corneal abrasions are common and painful, but not vision threatening.

However, more severe injuries which are vision threatening can occur. An estimate of 2,751 such injuries per year caused by racquet sports has been made by the National Society for the Prevention of Blindness. The estimate of eye injuries from racquet sports which the society uses comes from the U.S. Consumer Product Safety Commission. The Commission's estimates are based on reporting by a national sample of 119 hospital emergency rooms participating in the National Electonic Injury Surveilance System. These figures from 1973 to 1978 show 642 injuries from tennis, badminton, and squash. The numbers of reported cases has risen from 53 reported injuries in 1973 to 206 injuries in 1978 (1).

Although the National Society for the Prevention of Blindness has statistical data regarding emergency room visits with such injuries, they have no idea how many injuries are seen in private physician offices and clinics throughout the United States.

There have been ranges of estimates of the increasing numbers of people playing tennis and racquetball in addition to the sports of squash and badminton. There are estimates of between 12 million and 40 million tennnis players in the United States and approximately 6 million to 8 million racquetball players.

A previous paper, "Racquet Sports, An Ocular Hazard, "by Paul F. Vinger (2), is based on a prospective study for 15 months indicating that the majority of injuries occured in the 30-50 age range; that tennis was a number 1 sport in regard to ocular injuries; that contact lenses as such provided no ocular protection against injury; and that regular glasses lenses were somewhat more protective than no glasses. Properly designed industrial plastic safety lenses or industrial or athletic frames considerably minimize the potential for ocular injury. He further found that the ball could ricochet off of one's own racquet, or that the injury could be initiated by the racquet itself rather than the ball.

A second article by Morton H. Seelenfreund, M. D., "Rushing the Net and Retinal Detachment" (3), also investigates the severe nature of tennis injuries causing retinal damage as a result of ocular contusion.

The mechanics of such injuries have been studied rather extensively, in particular, by Dr. Charles Schepens and Associates (4). By using some extrapolation of their data, i. e., the regulation-size tennis ball of approximately 6.25 to 6.57 centimeters in diameter and weighing 56 grams becomes a high velocity missile that can cause severe ocular contusion. A smaller ball such as is found in racquetball or even the small point of a shuttlecock also will represent a considerable high velocity missile traveling over 80 kilometers per hour. As the missile impinges in the unprotected eye, there is a high-speed deformity of the cornea and sclera which transmits the kinetic energy to the interior of the eye. Such energy can cause very severe intra-ocular damage.

In order to sample the occurrence of severe vision-threatening injuries, 797 ophthalmologists primarily in Illinois, Wisconsin, Iowa, Indiana, and Missouri were sent questionnaires. The questionnaire asked for the occurrence of severe eye injuries which they experienced in their practice over the past five years. This retrospective analysis of severe eye injuries included the following:

1. Hyphema--bleeding inside the anterior chamber of the eye
2. Cataract--an opacity of the lens inside the eye
3. Glaucoma--increased pressure inside the eye secondary to bleeding or scarring
4. Retinal damage, including tears, hemorrhages, detachments and retinal scars
5. Choroidal rupture
6. Rupture of the eye--cornea or sclera
7. Fracture of the wall or floor of the orbit

This questionnaire specifically excluded minor trauma such as corneal abrasions and periorbital lacerations or contusions which, although common and frequently painful, have minimal consequences to the integrity of the visual system.

The dramatic nature of such an injury, i.e., a tennis-attired, Perspiring, acutely injured patient lends itself to relatively accurate recall. When a range of injuries was given, e.g., 3-5 injuries per year, the lower number was chosen for tabulation purposes. When two or more injuries were sustained in the same eye, the most serious was tabulated, and the others were omitted: (e.g., if a hyphema and retinal detachment were reported for the same eye, no entry of the hyphema was made, and the injury was tabulated under retinal detachment.) For the purposes of this study, physical loss of the eye and/or permanent loss of vision were equated.

Other factors influencing the accuracy of this survey were the geographical distribution of ophthalmologists sampled. Primarily, the questionnaire was sent to ophthalmologists in the upper midwest, with the obvious limitation in this area on outdoor tennis and badminton play. Samples from

California, Florida, and Arizona might well reflect increased injuries because of the amount of increased exposure time.

Results

One hundred sixty-six ophthalmologists answered this questionnaire reporting 847 serious eye injuries over the past five years. There were 400 hyphemas without subsequent residual ocular damage, 9 hypehmas with sequelae (residual damage), but the damage was not specified. There were 267 eye injuries, the nature of which was not specified. In decreasing frequency, the following injuries were reported:

Iritis, 56
Retinal tears, 21
Retinal edema, hemorrhage, or scars, 20
Vitreous bleeding, 17
Laceration of the eyeball, 16
Orbital fracture, 15
Loss of the eye, 10
Retinal detachment, 5
Choroidal rupture, 4
Glaucoma, 4
Cataract, 3

Although the largest number of specified injuries is hyphema with out sequelae, there are certainly significant numbers of eyes requiring surgery or resulting in permanent loss of vision or the eye itself. Illustrative of this type of injury is the following: R.T., a 71 year old man, had cataract surgery associated with intraocular lens implantation and a resultant post-operative visual acuity of 20/15. Four months after surgery, he was playing doubles tennis and was struck directly in the operative eye by a tennis ball. The blow ruptured the eye 1/4 of the circumference of the corneal limbus with a blowout of the iris and a subtotal hyphema. The intraocular lens was not disturbed in any way, and surgical repair was performed promptly with a remarkable return of 20/20 vision six weeks after the injury.

Comment

Although the questionnaire is composed of a retrospective and anecdotal type of summary, this survey would tend to be in the same general degree of accuracy as other retrospective analyses. Since there are 9,000 ophthalmologists in the United States (5) an approximation of injuries as a result of racquet sports experienced per year can be made.

Serious vision-threatening or vision-destroying ocular injuries in the United States associated with the racquet sports is experienced at a minimum rate of 9,185 injuries per year. This estimate is 3.3 times the estimate provided by the National Society for the Prevention of Blindness in their previous study.

The emotional, physical, social, and economic costs of these injuries is staggering. By relatively conservative estimates, these injuries with their attendant medical care, hospitalization, x-rays, medications, and surgery, cost over 1.5 million dollars per year.

Protective eyewear of nylon, industrial type, athletic, or sturdy metal frames associated with industrial strength or plastic spectacle lenses (6), special protective frames, or the wear of an overmask could almost completely prevent all of these injuries and attendant disability.

Other recommendations are such as those made by Dr. Vinger, "We recommend the advice of an experienced racquet sport coach plus the good judgement of players. Players could reduce the potential for injury if they would wear eye-protective devices, develop a strategy to avoid being hit, and have a strategy to avoid hitting the opponent." Several of the serious injuries in Dr. Vinger's survey were "a shot fired in anger after the point was over". There were also injuries experienced when more than one ball was in play in the same court during warmup.

The Canadian Racquetball Association last September made eyeguards mandatory at all sanctioned events and such a recommendation should be required for the racquet sports of squash and racquetball. Whether or not such recommendations can be carried over into tennis and badminton are certainly debatable, but the injury rate experienced in this report seems to indicate that protective eyewear should be used in all the racquet sports.

Although tennis injuries are reported in this survey at three times the incidence of the next-leading injury sports of racquetball, this is generally in proportion with the estimate that there are 40 million tennis players in the United States and approximately 6 million to 8 million Americans playing racquetball.

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WHOSE/WHAT FORM TO TEACH: A BIOMECHANICAL APPROACH TO TENNIS INSTRUCTION

by

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ABSTRACT

In this paper the author makes a plea for flexible tennis instruction based on a logical application of selected mechanical principles to the game. Each principle is stated and implications for both "form" and outcome are given. Both groundstrokes and the serve are considered. The material has relevance for both instruction and feedback functions of the teacher or coach.

The theory of flexibility explains how many different players play well with so much different form among them. The flexible approach enables teachers to deal effectively with students by allowing for individual differences among them.

One of our objectives as tennis teachers is to help our students develop good form. There can be no disagreement among us over that statement. But there may be considerable disagreement when we try to decide precisely what good form is. And the argument may continue when we consider the question of who -- or what -- determines good form. I suggest here, as the central theme of this discussion, that good form is best determined by applying mechanical principles -- principles that explain fundamental movement patterns -- to what we see and do and hope to teach. Our knowledge of mechanical principles provides a scientific basis for our methods. It helps us make accurate analyses, sound judgments and unbiased interpretations. And it helps us make allowances for variations in form when necessary. The result for us is more effective teaching. The result for our students is a greater probability of success.

In all sports, "form" refers to the way of performing the basic skills of those sports. "Good form" implies economy of movement and motion, and it suggests a minimum of moving parts. It is more likely to lead to good performance than is bad form.

In tennis, form refers to the kind of swing, the stroke, used to make a shot. But, good form is not a set pattern, a grooved stroke. Rather, it is whatever sequence of movements enables a hitter to accomplish his purpose with the least expenditure of energy. In other words, form is relative to the task at hand. Each hitter's and teacher's choice of form should be determined by the objectives and purpose of each shot. For example, to hit a hard drive from deep in the backcourt to the opposite baseline, a great deal of body action may be needed. But to hit softly from service line to service line, arm action alone may be adequate.

The hitter's purpose may also vary between risk and certainty. And as it does, his form will vary from shot to shot. A looping topspin drive aimed close to a sideline may be needed to pass a net man. A long follow through and a high finish may be conspicuous and essential parts of this stroke. But a flat shot, or even a slice or chop, may be a better choice if the intention is merely to keep the ball in play during a backcourt rally. For this, the finish may be lower and shorter, giving the look of a very controlled swing.

Yet, the question remains: Who determines good form? Historically in tennis, the form (and often mistakenly, the style) of the current champion has been accepted as the classic pattern to imitate and to teach. As a result, the concept of good form changes periodically as new champions display form that differs from the accepted model. Often the differences we see are the result of varieties in physique, temperament, and personality. And just as often, these differences may not be suitable for some particular students of ours.

As teachers, we have to understand and explain the disagreements on form that often arise. To do so, we must consider that good performance does not always depend on good form. Players may have certain special qualities that enable them to perform well even with poor form. Strength, speed of movement, flexibility, reaction time, explosive power, eye-hand coordination, and leverage power -- these vary among individuals and affect performance.

Now, only a few of our students are likely to have an abundance of these qualities. The majority are likely to be average persons with average capacities for learning. True, with proper instruction, practice, and attitude, many can acquire the ability to play well. But even those with great potential may not benefit by adopting wholeheartedly the form of a current champion. They may do better by adapting only certain noticeable bits of form to their own personal strokes.

This is a subtle difference that we teachers must understand as we plan our instruction. We can offer as models the strokes of champions (or even our own strokes). But we should encourage and instruct students to adapt those strokes to their own individual needs and abilities. In other words, we should help our students decide what to copy and what to reject, what to experiment with and what to ignore. But first we must determine what can be made to work for each of them and what is beyond their capacities.

To do this accurately, we need a background of facts and information from which to work. The best source for these facts and this information is the study of mechanics, or more specifically, the branch of physics known as biomechanics.

The science of biomechanics investigates the consequences of forces that are the bases for human movement. By examining the effect of these forces on motions and bodies, biomechanics helps us establish some principles of motion. We can apply these principles to judge the validity of the form we teach, to relate cause and effect; to determine what is important and unimportant, possible and impossible. As a result, our teaching is likely to be more effective.

Principles of Motion

All principles of motion are based on the three well-known laws of motion formulated by Isaac Newton in the 17th century. Though the principles are usually presented as generalizations, I have changed them slightly here to make them apply to tennis. Following each principle, I give one or more examples of its specific application to a particular stroke or shot.

Though they all apply to one or more strokes, we should judge each principle carefully before applying it in our work. In a particular situation, a player may violate one principle in order to conform to another that is more appropriate. And in another situation, a recommended point of form may appear to be a denial of a principle. There may sometimes be no logical explanation for this. Nor may there be explanations for other techniques that appear to contradict one another and yet work successfully for different players. We may only conclude that human behavior is also determined by other laws (biological laws, for example) and that mechanical analysis is only one aspect of performance and teaching in sports.

This approach to teaching need not lead to dogmatic teaching. Obviously, there is more than one good way to hit a tennis ball. There is a range into which variations of form may fall and still be correct and efficient: it may be called a "range of correctness." We may best help our students by recognizing differences in physique, posture, and temperament, and by adjusting our teaching so that variation resulting from these differences are permitted, provided they fall within the range of correctness.

Motion in a tennis swing is the result of muscular force applied to the body's system of levers. In biomechanics, the term "lever" refers to a long bone or combination of bones, fixed at one end and free to move at the other end. A straight arm moved at the shoulder, a bent arm moved at the elbow, and the hand moved at the wrist are examples of levers in the body. They operate in a way that permits a hitter to generate considerable momentum, or speed, at their distal ends while applying only a moderate amount of force, or strength, at the fixed ends. Now, when the racket is held in the hand, it becomes part of this chain of levers and so momentum imparted to it. And from there, of course, momentum is transferred to the ball.

One particular characteristic of levers in motion can help us determine the efficiency of wrist action during a swing. When any one of these levers is used alone, separately, its distal end moves in an arc. Now, when the wrist moves the racket in an arc, the racket faces a different direction every moment. Only at one point in the arc does it face the intended target. And because the ball goes mainly where the racket faces, hitters must time their wrist action precisely to hit to their intended target.

But with a firm wrist, laid back enough to make the racket face the target, the timing of the swing need not be as precise. The racket will be facing the target longer, and as a result, hitters will have a contact area in which to meet the ball rather than only one contact point. And so if their intention is maximum control of direction, the laid-back wrist is recommended.

When hitters want more force than such a swing provides and can afford to risk missing the shot, a moderate amount of what can be called "controlled hand action" may be best. With this technique the wrist is straightened somewhat at impact from the laid-back position used during the backswing. The movement at the wrist combines with the arm and body action to provide additional racket speed and a harder hit. In other words, the function of the wrist varies with the situation.

But we may often have to suggest that students make a conscious attempt to prevent wrist action during the swing. They can do this simply by holding the racket firmly.

To demonstrate this have students extend an arm and an empty hand opposite the belt buckle at waist height. Then have them use loose wrist action to quickly move the hand back and forth, in a kind of fish-tail motion. Next have them make a tight fist with that same hand and ask them to repeat the fishtail motion. They'll find it difficult to do because movement at the wrist is restricted when the grip is made firm. The tendons of the flexor muscles of the fingers -- those used to make a fist -- are worked from the forearm and pass over the wrist in a way that restricts motion there. Explain then that for a firm wrist, they must have a firm grip.

In our work we try to help our students use the elements of movement -- space, force, time, and flow -- to swing more efficiently so as to hit more effectively. To do this we must understand how our students can use space to their advantage, how they can swing with light or strong force, how they can move at fast or slow speed, with free or restricted flow.

The branch of physics known as biomechanics provides a sound, logical basis for the instruction we offer on these points of form. It helps us evaluate the techniques of and examine precise details of our players' swings whether they be beginners, intermediates, or world-class. It also helps us establish certain broad fundamentals of stroking.

Biomechanics examines the effects of internal and external forces on the human body. It helps us establish some principles of motion based on Newton's well-known laws of motion.

Motion in tennis swings is the result of muscular force applied to the body's system of levers. This is not to imply that brute strength is necessary. Rather, the lever system makes it possible for hitters to develop sufficient momentum during the swing with only a moderate amount of strength. The force applied to the levers is muscular, but the force applied to the ball is a result of momentum.

But hitters don't always want maximum speed. As often as not, they are more concerned with precise control while swinging only moderately fast or even slowly. For this a moderate amount of strength is necessary to control the racket, to move it quickly, then slow it down, to set it properly for the shot intended, and to resist the force of the oncoming ball. Obviously, several mechanical principles can be applied in tennis instruction. Even so, readers are cautioned not to infer that all of these few apply to every player or to every stroke. Instead, I have assumed that most readers know enough about physiology, anatomy, mechanics -- and tennis -- to evaluate what I've said and so apply all, some, or none of it in their work. And for readers who choose the last of these three courses of action, I can only say that discussion, and sometimes controversy too, is good for the game.

TENNIS RACKET TESTING RELATED TO "TENNIS ELBOW"

by

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Abstract

Factors attributed to the cause of "tennis elbow" include equipment problems, performance variations, and anatomical differences. The purpose of this investigation was to analyze and compare the forces transmitted to the hand during a swing (with special emphasis on the impact forces) with various racket types and string tensions. It was concluded that impact forces were always greater than the forces on the hand during the swing, and varied from two to five times more depending on where the ball impacted the racket. It soon became apparent that the big difference in forces transmitted to the hands was not in racket differences, but in the position of impact. It was difficult to measure the differences in rackets because the overwhelming dominant factor that caused force changes was the distance of impact off center from the long axis. Therefore, the racket comparisons are not presented and certain general facts relating to racket design are presented instead. Also, helpful suggestions, that seem more appropriate for helping the tennis player, are presented relative to protecting the elbow.

There are many factors which predispose one to the malady called "tennis elbow". There are mechanical problems relative to equipment, performance variations, and anatomical differences. An extensive study on the relationship of the racket to the arm was undertaken to rank most rackets on the market. When the project started, the intention was to present numerous tables on flex, string tensions, different makes of strings, and show the force changes transmitted to the hand using different combinations of racket flex and string tensions. It was found that the impact forces were always greater than the forces on the hand during the swing, and varied from two to five times more depending on where the ball impacted the racket. It soon became apparent that the big difference in forces transmitted to the hands was not in racket differences, but in the position of impact. It was difficult to measure the differences in rackets because the overwhelming dominant factor that caused force changes was the distance of impact off center from the long axis. Therefore, the racket comparisons are not presented and certain general facts relating to racket design are presented instead. Also, helpful suggestions, that seem more appropriate for helping the tennis player, are presented relative to protecting the elbow.

Racket Testing

Sixty three rackets were obtained for testing with eleven selected frames restrung at different tensions, and also with nylon instead of gut. Each racket was measured for weight, balance, flex, and the center of percussion was determined. The testing consisted of:

1. A static racket held in a vise and hit with a ball thrown from a machine at 40 and 60 m/h. The racket was clamped as solidly as possible, and then the tests repeated with the rackets clamped loosely with foam padding around the grip to assimilate the hand held racket.

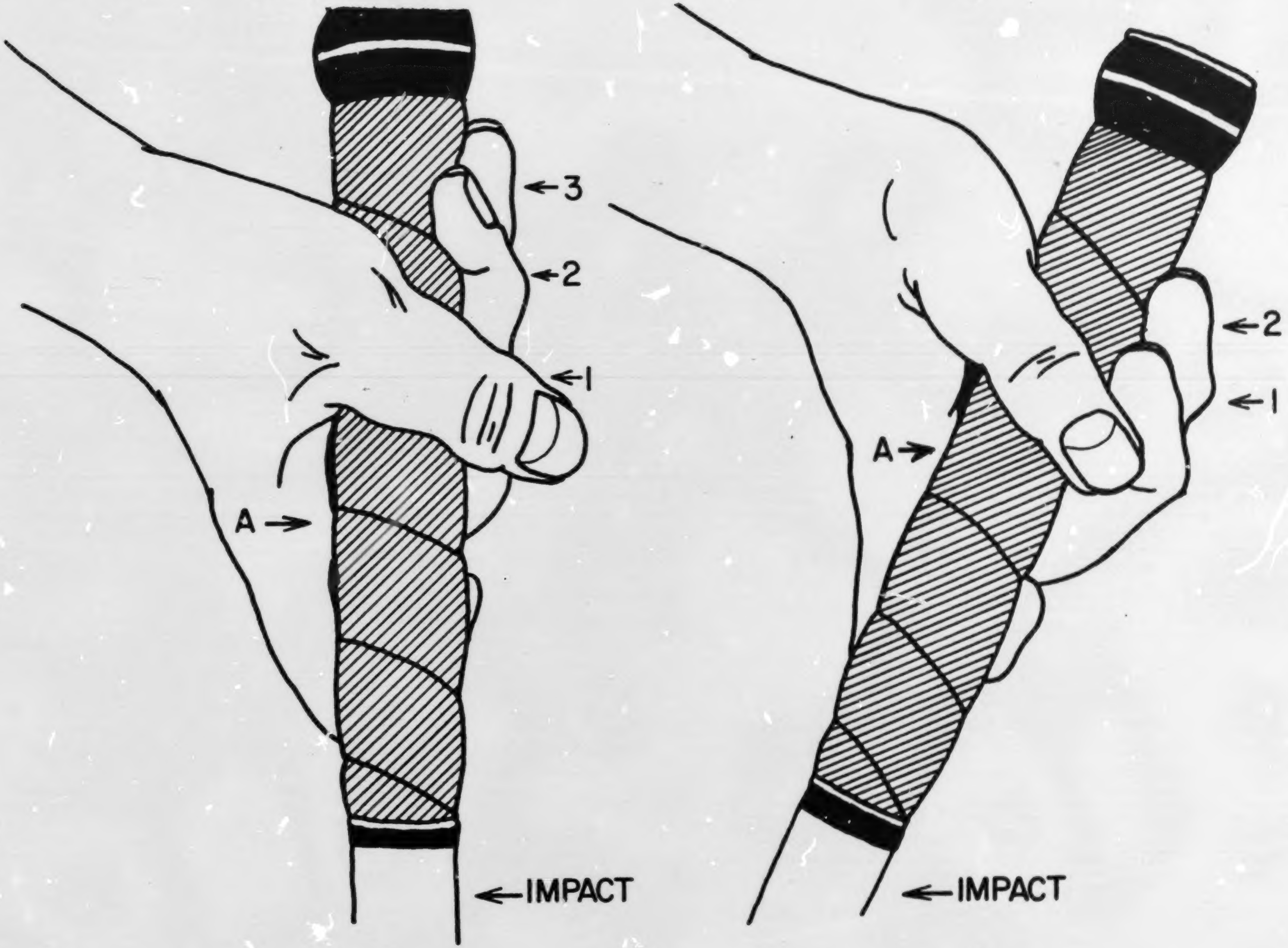
2. A racket clamped in a moving arm, with sponge around the grip, was met by a ball from the ball throwing machine. The ball velocity was controlled at 55 m/h and the racket impact point velocity was 30 m/h for a closing speed of 85 m/h.. The sponge around the grip made it possible for the racket to twist if hit off center similar to a hand held racket.

3. Serves and ground strokes were hit by two tennis players with a pressure transducer between the racket and the hand. This dime sized transducer was placed at the base of the index finger which is the pivot point of the racket during impact (Figure 1). Serves were hit at first serve velocities but counted only if they were within the service court. The ground strokes were hit from the baseline off a ball machine, and the force transmitted to the hand recorded only if the return was hit within two feet of the net top and within two feet on either side of the service line.

4. Games were played with the pressure transducer in the hand to compare results with the controlled tests.

Figure 1

The impact pivot point (A), and the counter force to the impact (1,2,3).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Determination of Ball and Racket Velocities

Ball and racket velocities were measured from films taken of matches on the grass of Forest Hills and the composition of Longwood. The velocities measured aided the selection of the speeds used for the laboratory tests. The velocity measurements obtained from game films varied with the court surface, but were reduced to the following generalizations:

1. The first serve left the racket at 110 to 115 m/h; the ball slowed to 80 to 85 m/h before it hit the service court, and the ball slowed down after the bounce to about 50 m/h when it was hit by the receiver. The second serve had an initial velocity of 75 to 80 m/h and had slowed to 30 m/h when struck by the receiver.

2. The return of serve averaged about 50 m/h from the time the ball left the racket until it bounced, and then slowed down to about 30 m/h for the server to hit.

3. Subsequent ground stroke rallies showed the ball velocities to be between 42 and 52 m/h from racket to bounce, and 13 to 30 m/h from bounce to opponent's racket. A heavy top spin hitter of ground strokes will hit a ball coming into their racket at 25 m/h with a glancing upward movement across the ball at 45° to 55° putting top spin on the ball of 4 to 6 radians per second.

4. A typical doubles game has a serve averaging 65 to 75 m/h from the racket to the ground, rebounding to the receiver at 33 to 37 m/h. The server moves in and volleys a ball going 40 to 50 m/h and consecutive volleys with all four at the net will have the ball moving between 35 and 45 m/h.

The Racket-Ball Closing Velocities

An important factor emerged after relating ball velocity to the horizontal velocity of the center of the strings. Players adjust the direction of their swing and the length of the backswing so the closing velocity of the racket and ball does not exceed 100 m/h. A slow ball will be swung at fast, a return of serve probably sliced with a reduced backswing, and a fast ball hit with a greatly reduced swing. Therefore, not only is the time available to make a shot an important factor, but the hand holding the racket will tolerate a limited force at impact. Four examples illustrate this point:

1. Service - ball velocity = 0, racket velocity = 90-95 m/h
2. Return of serve - ball = 50 m/h, racket = 45-50 m/h
3. Ground strokes - ball = 25-60 m/h, racket = 50-30 m/h
4. Volley - ball = 20-70 m/h, racket = 45-0 m/h

Results

Test 1 - static racket. The impact of a ball on a static racket was controlled so that all balls were thrown to hit the center of the racket. The outgoing velocity showed no difference between the solidly clamped rackets and the rackets with foam rubber around the grip. Also, no significant difference existed between various makes of rackets and gut or nylon. Strobe pictures were taken at 70/sec. to measure the velocity of the ball in and out.

Test 2 - moving racket. The racket was propelled at 30 m/h and motion pictures were taken at 200 frames per second to measure the ball velocity. Several hits were made on each racket to obtain variations in outgoing ball velocities when the impacts occurred on center, high, low, and off center from the long axis. The more off the long axis the impact, the more the racket would twist, and the less the velocity of the ball after impact. A ball that hit the racket one inch off center had a reduced velocity of about 15%, and a ball hit two inches off center had a reduction of about 40%. The largest percentage reduction in ball velocity measured was 50%. A ball struck anywhere on the long axis had very little variation in ball velocity after impact, but there was a 10% reduction for balls hit near the tip of the racket. Distinguishing between racket characteristics was not attempted because the dominant variable was the distance off center of ball impact regardless of the racket used.

Test 3 - pressure transducer. The measurement of the force transmitted to the hand was influenced the most by the amount of off-centerness of the impact. The force on the hand during the ground stroke test varied from 28 to 56 lbs., and during the serves from 30 to 70 lbs. Volleys were measured while hitting a controlled ball velocity of 40 m/h from a ball machine, and the forces on the hand varied from 18 to 48 lbs. Balls that were hit toward the tip of the racket and off center recorded the highest forces for all strokes and with all rackets.

Test 4 - pressure transducer during play. No attempt was made to film the play, so the position of the ball on the racket could not be correlated with the forces recorded on the oscilloscope as in test 3. There was a wide variation in the forces recorded, but all were within the ranges found in the controlled tests.

Forces on the Hand

Figure 2 'a' through 'j' presents several force changes on the hand as recorded on an oscilloscope. The hand tightens on the grip in preparation for the impact, and the impact then adds to the force on the transducer which is between the hand and racket. Figure 2a shows one of the largest forces on the hand; a first serve hit near the tip of the racket. Figure 2b shows a center hit serve, and 2c shows a double peak due to a ball hit low on the strings toward the throat of the frame. The frame is set into a different vibration pattern when struck high or low as the tip moves backward first when hit high and forward first when hit low. A ball hit low on the strings during a serve usually produces less force on the hand.

Figure 2d shows a hard hit ground stroke. The swing was fast and the ball was struck on center resulting in a high ball velocity. The high force build up is the hand squeeze just prior to impact in anticipation of a large force of impact. Had the ball been struck off center, the racket would have remained stable enough to result in a good shot. However, without this firm grip, an off center hit would have resulted in a loss of ball velocity and more chance of error. Figure 2e shows a slower swing with less hand pressure prior to impact resulting in a slower ball velocity of a center hit ball. Figure 2f shows the same swing speed as in 2e, but of an

Figure 2

The force of impact on the hand as transmitted through a force transducer between the hand and racket.

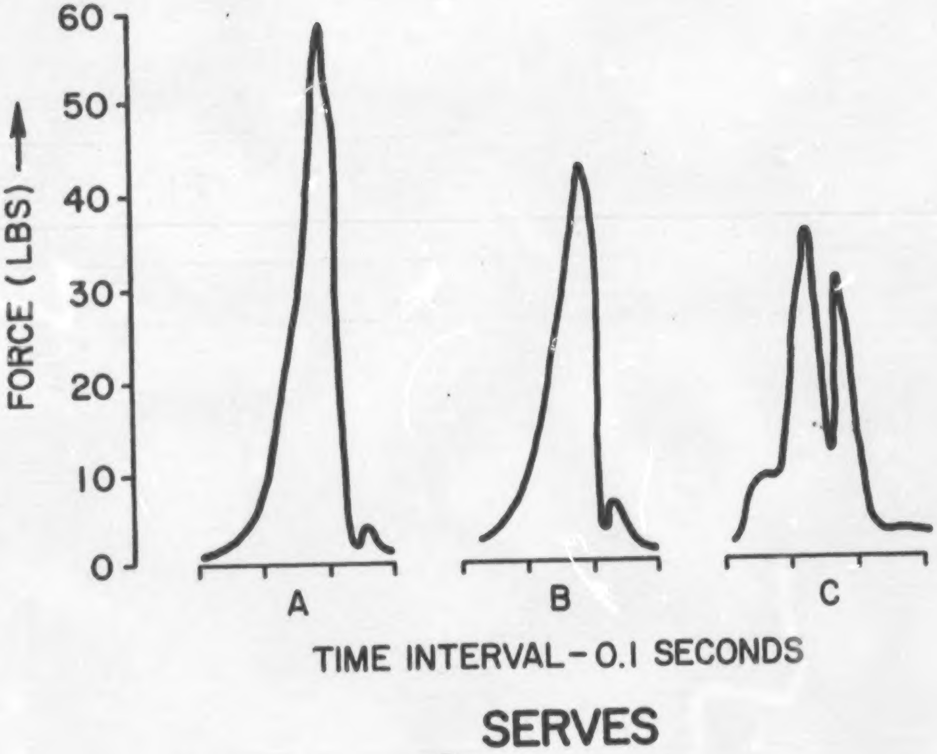
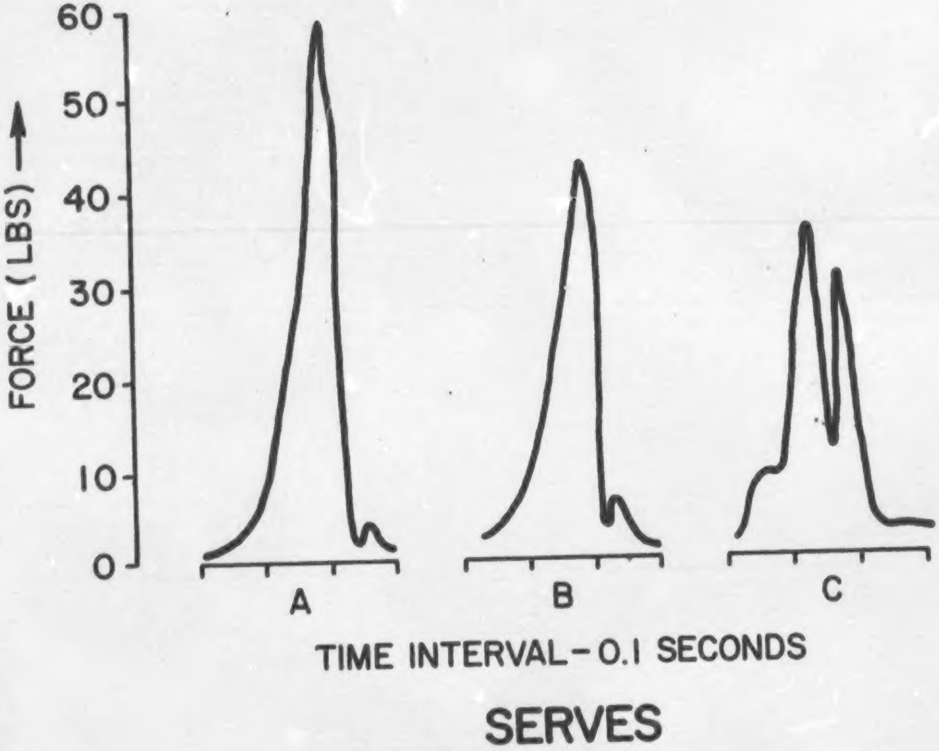
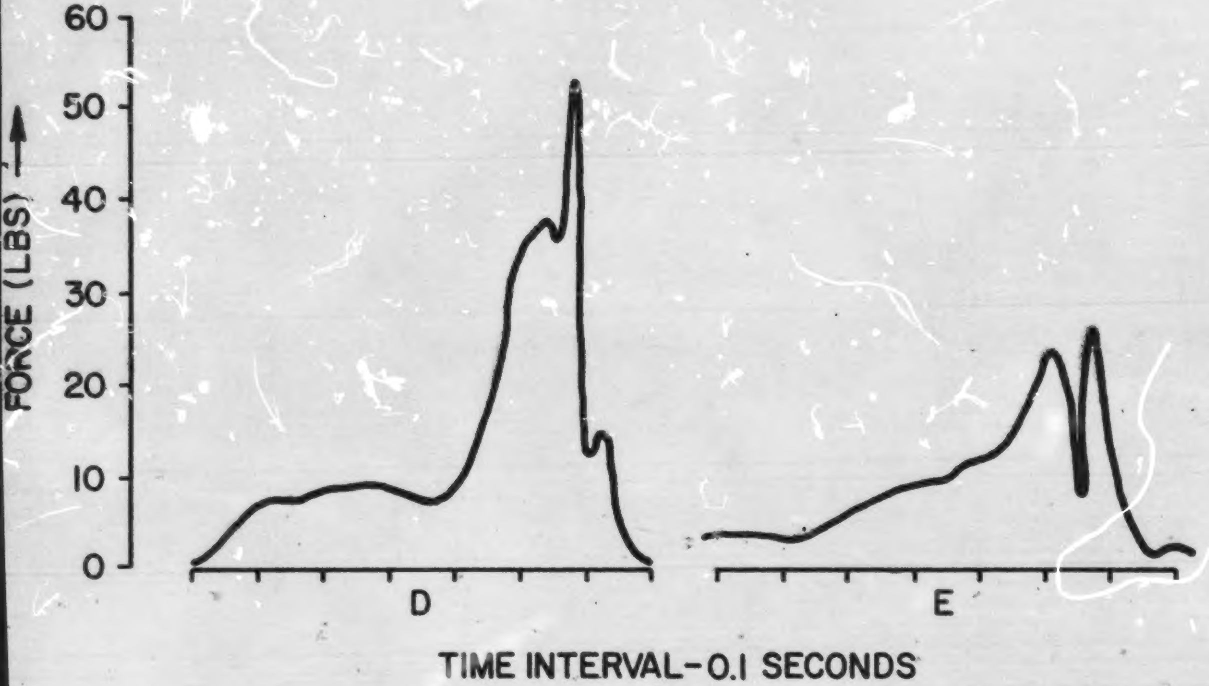


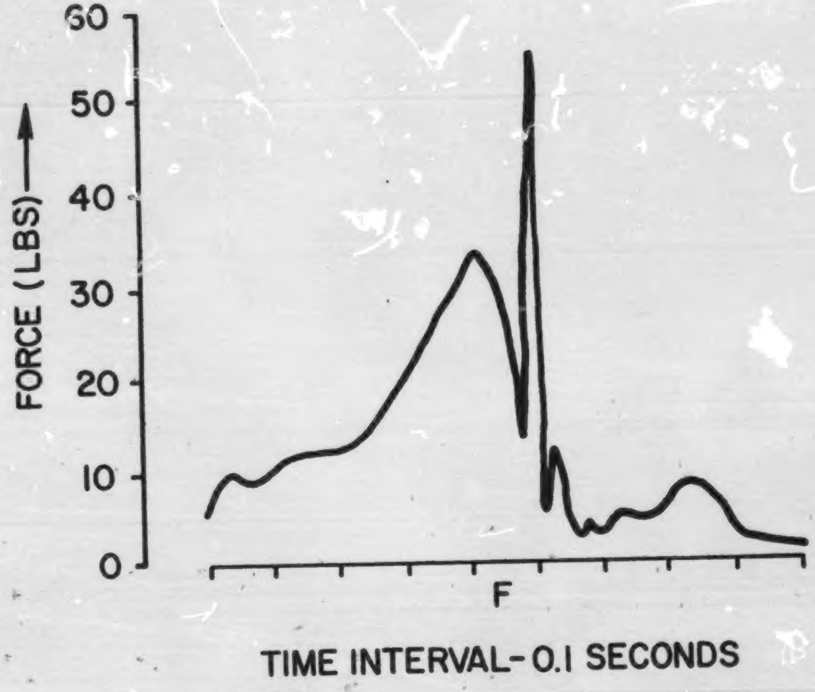
Figure 2

The force of impact on the hand as transmitted through a force transducer between the hand and racket.

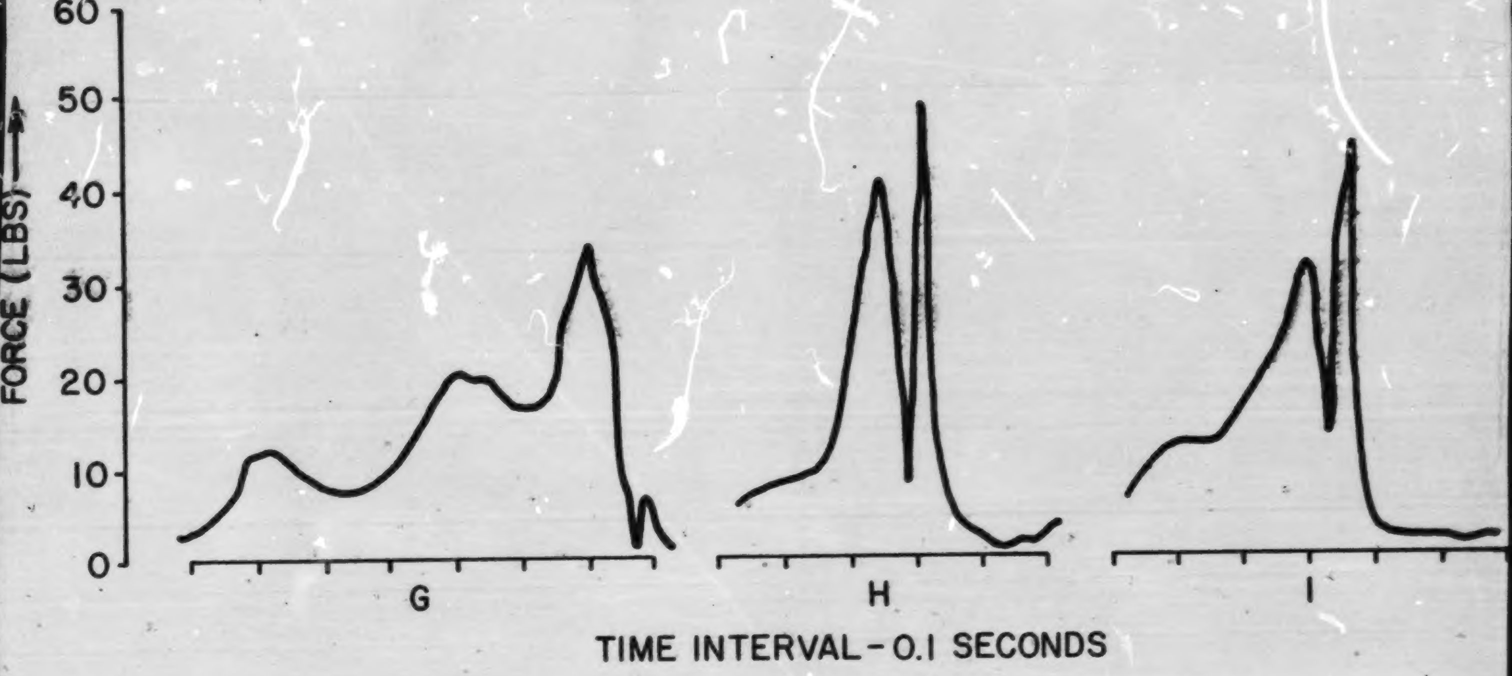




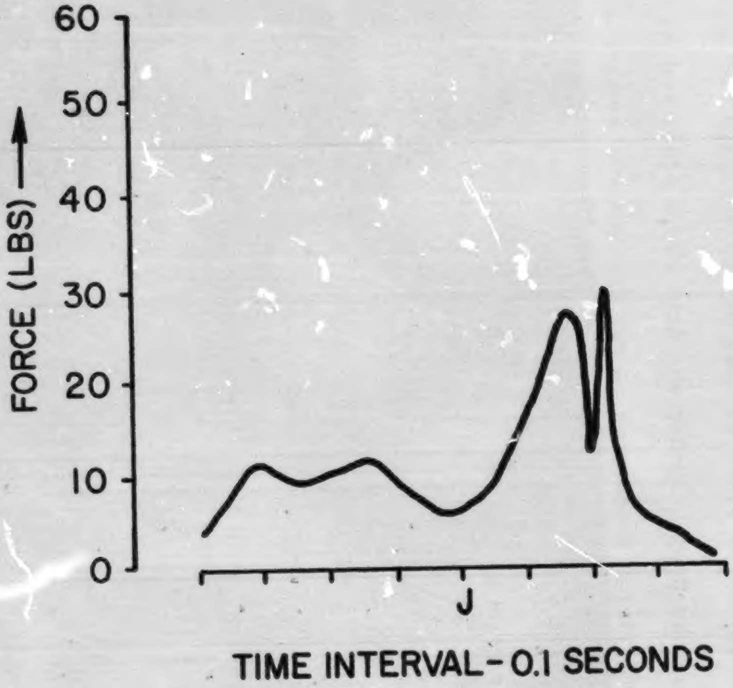
GROUND STROKES



GROUND STROKES



VOLLEYS



VOLLEYS

off center hit which produced a larger force on the hand.

Figure 2g shows a volley hit off center and low toward the throat, while 2h shows the ball hit off center and toward the tip. Figure 2i shows a well hit center shot resulting in a high ball velocity, while 2j is another well hit volley, with a slower ball-racket closing speed, resulting in a lower ball velocity than 2i. The hand squeezed harder prior to the impact of a fast closing ball and racket in anticipation of the larger force to be sustained, and the squeeze takes place about 0.2 seconds before impact for ground strokes and volleys. This is not true of the serve, however, where the total body throwing motion requires a great deal of hand flexion just prior to impact, and too tight a grip would interfere with the proper serving motion. In as much as the ball is under the servers control and has no horizontal velocity, the hand squeeze can be precisely timed with the impact. Good hand firmness at impact is just as essential during serving as it is during other strokes to counter any off centerness of impact.

Interpretation of the Tests

Everyone must sustain an unavoidable force at ball impact to play well, because playing without a firm grip reduces the quality of play greatly. Everyone also hits a majority of their shots off center, good players as well as poor players, because the best players are hitting balls at higher velocities. Off center hits produce the largest forces and these forces are transmitted to the muscle attachments of the forearm, and the muscles attaching to the lateral epicondyle of the elbow are particularly vulnerable to injury. This leaves only two options to help avoid injuries; lower the forces of impact or increase the muscular strength. If the force to be sustained can not be matched by the strength of the muscles involved, something must give. All players would benefit from strength exercises that include supination and pronation as well as flexion and extension of the hand. The test results indicate that several factors can be helpful to a tennis player for keeping the forces on the body minimal. Suggestions are presented relative to: 1. racket characteristics, 2. playing conditions, and 3. the anatomy of the body.

Racket Characteristics

Use a large, high friction grip. The counter to the racket twist produced by an off center hit must be applied tangent to the grip surface, and the squeezing of the hand produces this counter force. A large grip is better than a small one because the radius from the grip center to the surface is increased, which decreases the need for hand squeeze. Also to counter twist, a high friction grip is better than a smooth one, and ridges are better than a circular grip.

Have adquate weight in the racket head. The center of percussion is in the middle of the strings if the pivot point is considered to be 4 3/4 inches from the end of the grip (the base of the index finger). The fingers must counter the force of the impact with pressure from the front side as previously shown in figure 1, and the hand must be squeezed to counter the twist of off center hits. The racket would be more stable and have less need to squeeze hard if the center of percussion were raised and more weight placed on the outside edges. The tests showed that a ball hit high and off center is the worst combination for the hand to sustain trying to maintain racket stability. The stress on the outside of the elbow while hitting a backhand, with impact toward the tip and off center to the high side, is a major problem for causing injury. This probably explains why so many players have gone to a two-handed backhand for maintaining good racket stability while alleviating the stress on the arm. Those players who have remained with wood rackets, or a composite of equal head weight, and stayed with the larger grips used in the past, have probably been playing better and with less arm trouble than if they had changed. The trend toward light heads and small grips is in the wrong direction.

Match the racket flex and string tension. With off center hits being such a dominant factor in this study, only general statements are made regarding the differences in rackets. The indication is that most rackets should be strung between 55 and 60 lbs. unless there is a small or large head. Head weight seems to be more important than flex, and the string tension seems to be more a matter of preference than producing variations in ball velocity or shock absorption. Generally, a stiff frame should have slightly less tension than a flexible frame. Any combination of racket and string tension that produces a low shock to the hand also produces the lowest ball velocities. Thus a swing that produces a higher ball velocity automatically produces a higher force on the hand. Higher swing speeds result in less racket control which results in more errors and probably in just as many sore arms.

Playing Conditions

Play at reduced levels of ball velocity. If you are just beginning the tennis season, or you already have some elbow pain, play is possible if the ball velocity is kept relatively low. This keeps the force of impact low and reduces the number of extreme off center hits. Figure 3 provides a means of establishing the maximum ball velocity that would be best for most people. The coefficient of restitution of a ball drops off rapidly after it reaches 50 feet/sec. (34m/h), so faster swings with more muscular effort are not rewarded proportionately with greater ball speeds. The force of impact on the hand also increases rapidly above 50 feet/sec., and these high forces are to be avoided. If you have a sore arm, don't play games but manipulate your practice. Following is a list of suggestions to practice at a low force level:

a. Play on the slowest court surface possible, which is clay or a high friction hard surface.

b. Warm up gradually starting off court with some forearm exercises of low intensity and then hit ground strokes slowly keeping the closing velocity of racket and ball low.

c. Don't play at all against a hard hitter.

d. Don't volley balls going long when standing on the baseline. It only takes one hard impact to cause a problem.

e. Stand still when serving and swing slowly or don't serve at all. When considering other sports where impact occurs, the tennis serve is the highest. A golf drive applies about 30 lbs. of force, a racketball serve about 50 lbs., and a tennis serve can go as high as 70 lbs.

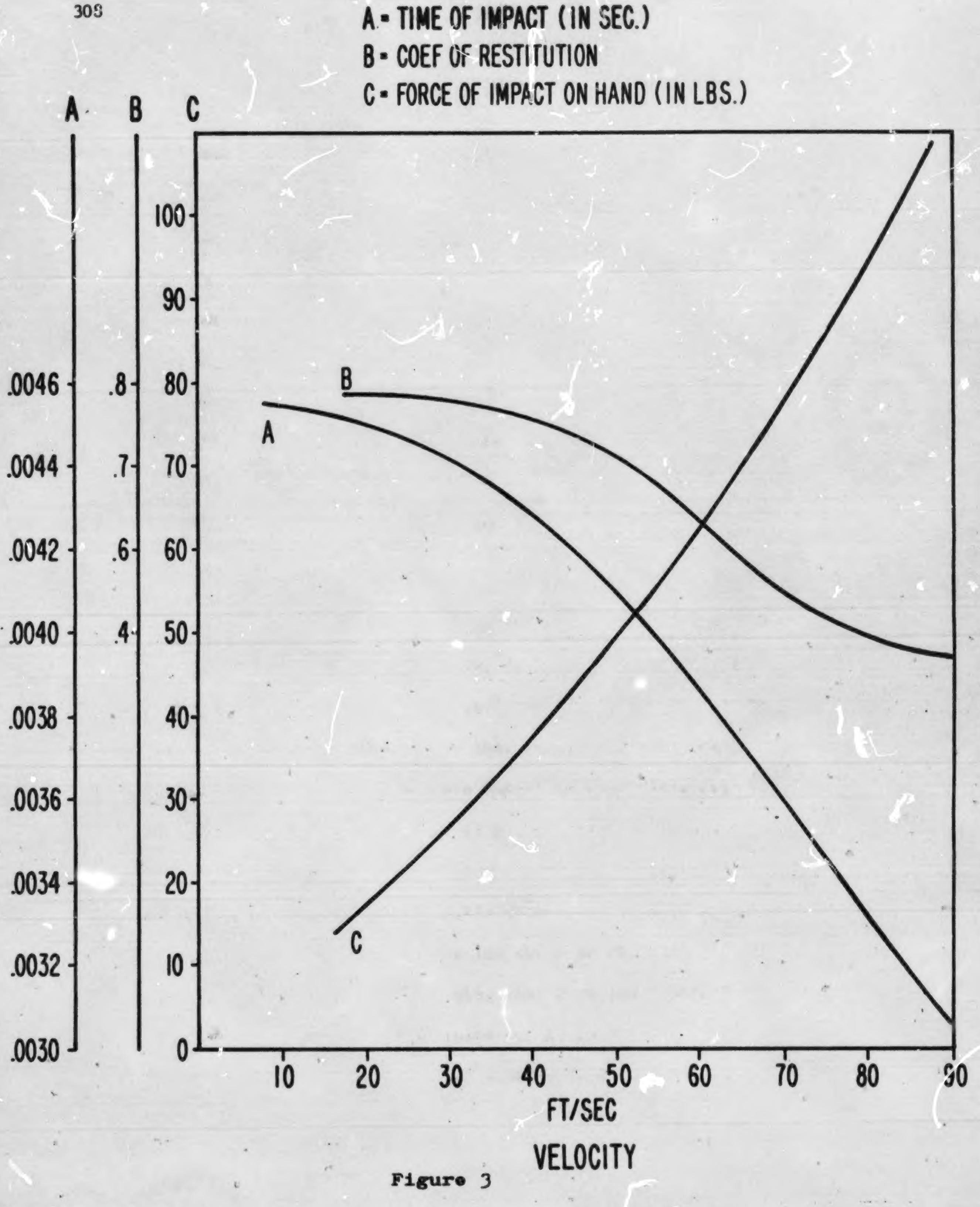


Figure 3

The relationship between the time of impact, coefficient of restitution, and force of impact on the hand.

f. Don't hit any overhead smashes as off center hits are likely.

g. Play with the wind at your back at all times if you have a congenial practice partner.

h. Use good balls, not dead ones.

i. If you do play games, make it doubles so you can serve with the wind, pick the receiving court to protect the shot that hurts your arm, and then give way to your partner on overheads.

j. Practice volleys with both players at the net hitting only medium-paced balls.

k. Avoid returning serves as off center hits are very likely. If you do play, stand further back than normal when receiving.

l. Use a two-handed backhand, if only temporarily, if pain occurs at impact.

m. Play only a short time.

n. Don't apply any large forces to the hand while off the court. Using a screw driver, shaking hands, and other daily habits that produce large forces must be avoided.

The Anatomy of the Body

Having the hand in alignment with the forearm with the elbow slightly bent is the most desirable position at impact, as you can not squeeze the hand firmly when it is out of alignment. Swinging properly with movement onto the front foot has nothing to do with reducing the force of impact, but swinging properly insures a strong strength of position of the hand and forearm. Whether you are standing on your head or on your front foot makes little difference; the arm must sustain the impact. Moving onto the front foot may produce greater racket velocity in the most efficient manner, but this would also require sustaining a greater impact force. Therefore, hand position is a very important factor for playing good tennis while avoiding arm problems.

A much disregarded factor is the muscular ability of a person to grasp a racket firmly. The strength of a muscle depends on its being innervated properly. Muscle function can be less than 100% if nerve impairment exists. One should check with a chiropractor to examine the neck if there is a history of an elbow problem. Strength exercises are not rewarded if nerve function is not normal, and arm problems are likely to occur when the pace of hitting the ball is increased.

Tennis players develop an unbalanced musculature of the upper body because of the one-sidedness of the sport. A dropped right shoulder, low back problems, and a slight scoliosis are common among those who have participated for years without doing muscle balancing exercises. To prevent problems from occurring, all tennis players should use weight exercises to re-establish good muscular balance throughout the entire body.

EVALUATION

EVALUATION:

A LOOK AT WHAT WE'VE DONE: SUGGESTIONS FOR WHAT WE SHOULD DO IN THE FUTURE

by

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Abstract

An evaluation developed by the author was conducted among those who attended the "National Symposium on the Racquet Sports." This one-page, 13-question evaluation was intended to gauge the reaction of the participants to the relevance of the subject matter of the symposium and to the format and method of presentation.

Of the 74 people who attended the Symposium, 31 people (42%) completed the evaluation. The vast majority felt that the Symposium adequately covered the topics listed in the Symposium brochure (87%), that the Symposium was worth their time and the expense involved (93%), and that the information shared would be applicable to their own job or research situation (79%). The length of the Symposium was judged to be about right (90%), as was the educational level (90%). The majority felt the number of sessions were about right (71%); however, a significant number (23%) felt there were too many.

The mechanics of the Symposium fared well, with the publicity getting mixed reviews, and the accommodations and registration procedures getting above average ratings. A large number (84%) felt that the Symposium provided above average or excellent opportunities for discussion with conference speakers and fellow participants. Additionally, a significant group felt that the Symposium exceeded their expectations for learning (67%).

The most beneficial sessions seemed to be the various clinics, since they presented practical information that could be used immediately. The least beneficial sessions seemed to be the scientific presentations, due to the participants' feelings that presenters did not interpret the results to show applicability to teaching. Written comments suggested several areas that might be improved upon the next time the program is presented.

Evaluations usually attempt to perform a two-part service. On the one hand, there is the desire to find out how well the program met its goals; and on the other hand, if there are plans for offering the program again, there is a desire to find out how to improve the next program. We had both these desires when we developed the evaluation for the "National Symposium on the Racquet Sports." We realized that the participants would be hurrying to catch planes, etc., on Saturday afternoon when the Symposium ended, so we developed a one-page, 13-question evaluation selected from an item pool developed by Dr. Donald Campbell of the Program Development section of the Office of Continuing Education and Public Service at the University of Illinois at Urbana-Champaign. The major intent of the evaluation was to gauge the reaction of the participants to the subject matter of the Symposium in terms of its applicability to their own situations. We asked that question directly, as well as several variations of it for correlation purposes. In addition, since we anticipate conducting this Symposium again, we were most interested in finding out how effective the format of the Symposium had been, and how it could be improved.

There were 74 participants who attended the Symposium. The evaluation was completed by 31 participants (42%). Not everyone completing an evaluation responded to every question. In our analysis of responses, we used only valid responses; hence, the n-value varies for each question. Figure 1 displays the actual evaluation with the tabulated results superimposed. The written responses to questions #12 and #13, plus written comments, follow figure 1.

The first question ("The topics listed in the conference brochure were adequately covered.") was meant to see if our publicity adequately described what we hoped would take place. The majority of those responding (87%) felt we had accurately explained in our material what would be covered. One area that did seem hazy to some, as explained in the "comments," was how much opportunity there would be to participate in the teaching clinics.

The second question ("I will be able to apply what I learned at this conference to my own situation.") received a favorable response from 79% of the participants. However, the remaining 21% were unsure or did not think they would be able to apply the information, especially the information presented in some of the scientific sessions, to their own situations. Of those attending the Symposium, 93% felt that "This conference was worth the time, effort, and money" (the third question).

In an effort to plan for the next Symposium, we asked three questions directly related to the format of the Symposium. Fully 90% felt that the length of the Symposium (question 4) was about right. Regarding the number of sessions (question 5), 71% thought the number was about right. A significant minority (23%) felt there were too many. In the "comments" section, several people wrote that they would have preferred more time with the teaching clinics. This might be a reaction to several comments that the scientific sessions, at times, did not go that extra step of indicating how the research could be applied to teaching. Almost everyone (90%) felt that the educational level was at their level. Several people wrote in the comments that too much time was spent on the basics of teaching, and one person wrote that the scientific presentations got a little too technical.

Since it seems probable that we will hold a second Symposium, we asked three questions regarding the mechanics of the Symposium. Most people thought that the publicity could have been better (67% thought it was average or below). Several people took considerable time to write helpful suggestions. On the other hand, registration procedures (question 8) and the accommodations (question 9) received uniformly high marks.

Much of what participants get from a conference comes from their interaction with speakers and fellow participants outside regularly scheduled sessions. Question 10 ("The opportunities I had for discussion with conference speakers or participants were...") indicated that 84% of those responding felt that this facet of the Symposium was above average or excellent when compared to similar programs.

Participants come to a program with personal expectations. These expectations are based on what they have read in the publicity, and are modified in light of their own needs. In addition, meeting expectations become an indicator of "success" for the participants. The response to question 11 indicated that 67% felt that the Symposium exceeded their expectations.

Even though many people will say that a program has been successful, there are parts that are more well received than others. To give participants an opportunity to tell us what they thought were the best and worst sessions, we added two open-ended questions. Responses to question 12 ("Which session was the most beneficial for you? Why?") showed that the teaching clinics were the overwhelming favorite. Vic Braden was mentioned 21 times in 28 responses. The major reason why Vic Braden's and the other clinics were chosen was the applicability of the presentations to the participants' individual situations. (Actual responses are appended.) Responses to question 13 ("Which session was the least beneficial for you? Why?") showed that the scientific sessions, because many did not draw practical conclusions or make recommendations, were not viewed as being as beneficial as other sessions. Several presenters were criticized for being too general.

As with any form (an evaluation being no exception) which asks people to make choices, it is necessary to provide respondents with an opportunity to write whatever is on their minds. Of the 31 people who completed the evaluation, 23 (74%) took time to make additional comments. A major complaint was that there was not more time for participation, or that participation was not a part of the Symposium. In addition, several people felt that Thursday was too long (with a night session).

Even as this Proceedings is going to press, plans are underway for "The Second National Symposium on the Racquet Sports." The results of this evaluation will go a long way toward improving the upcoming Symposium. We would like to take this opportunity to thank those who took time to complete the evaluation.

Figure I

NATIONAL SYMPOSIUM ON THE RACQUET SPORTS
June 13-16, 1979

Symposium Evaluation (n=31)

As part of our effort to increase the effectiveness of future programs, symposium planners would appreciate your reactions to the subject matter of the symposium and its presentation. It is important that every participant complete this form, so that the reactions of the total group will be reflected.

			Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
1.	The topics listed in the conference brochure were adequately covered.	(n=30)		4/13%		21/70%	5/17%
2.	I will be able to apply what I learned at this conference to my own situation.	(n=31)		2/6%	5/16%	19/63%	5/16%
3.	This conference was worth the time, effort, and money.	(n=31)		1/3%	1/3%	16/52%	13/41%
4.	The length of this conference was . . . a. Too short (Circle No. 1) b. About right (Circle No. 3) c. Too long (Circle No. 5)	(n=30)			about right 27/90%		too long 3/10%
5.	The number of sessions scheduled for this conference was . . . a. Too many (Circle No. 1) b. Just right (Circle No. 3) c. Too few (Circle No. 5)	(n=31)	too many 7/23%		just right 22/71%		too few 2/6%
6.	The level of this conference was . . . a. Too elementary for me (Circle No. 1) b. Just right for me (Circle No. 3) c. Too advanced for me (Circle No. 5)	(n=30)	too elementary 2/7%		just right 27/90%		too advanced 1/3%

			Poor	Below Average	Average	Above Average	Excellent
7.	The publicity for this conference was . . .	(n=28)	2/7%	6/21%	11/39%	7/25%	2/7%
8.	Registration procedures for this conference were	(n=30)		2/7%	7/23%	10/33%	11/37%
9.	The accommodations were . . .	(n=29)			6/21%	11/38%	12/41%
10.	The opportunities I had for discussion with conference speakers or participants were . . .	(n=30)			5/16%	11/37%	14/47%
11.	The degree to which this conference met my expectations for learning was . . .	(n=31)		1/3%	9/29%	15/48%	6/19%

12. Which session was most beneficial for you? See following pages for written responses.

Why? __________

13. Which session was least beneficial for you? See following pages for written responses.

Why? __________

Please feel free to use the back of this form to expand or comment on any of the questions asked or to add any comments you feel would help us in planning future programs.

KEY: x/y% where x = the actual number of people who marked that response
y% = the percentage of the total response of the people who actually responded to that question.

Figure 1b
Question 12: Which session was most beneficial for you? Why?

1. As a tennis coach I particularly enjoyed Vic Braden, Chet Murphy, and Joanne Taylor. I believe I can apply some of their information to my college coaching.
2. Demonstrations on teaching technique.
3. Braden - Murphy - Glick - Good presentation--joke in panel was offensive to me and rather pointless. My area is primarily tennis.
4. Braden and Gowitzke and Waddell. I teach tennis and badminton.
5. Vic Braden's, Chet Murphy's motor learning and teaching strategy. Coaching cues were excellent; research session very very good.
6. Vic Braden's tennis. New ideas were presented to make one think.
7. Braden--tennis clinic; Ford--tennis serve. Those sessions were closest to my area of responsibilities and interests.
8. Waddell and Braden as they presented visual/verbal information about strokes then gave teaching aids that hopefully, I can use. Also, Glick's information on tennis elbow as I teach Kinesiology.
9. Tennis analysis--Vic Braden, Chet Murphy, Joan Ramey-Ford. They covered my area of interest and Joan gave practical, specific information.
10. Vic Braden's Teaching Clinic. Picked up teaching tips.
11. Racketball. Will be teaching it for the first time this coming year.
12. Difficult to answer.
13. Sports medicine and biomechanics; motor learning and teaching strategies. Informative and applicable--provides rationale and research to back up key teaching points.
14. Plagenhoef, Braden, Murphy. Very stimulating--good ideas.
15. Vic Braden and Gowitzke. Braden--entertaining and information; Gowitzek--I do not know anything about this information.
16. Stan Plagenhoef--and parts of Vic Braden's sessions--because they were realistic in their approach.
17. Braden, Glick. Useful to my interests in coaching and physical therapy.
18. Vic Braden. Tennis pro--most information from him will help in my teaching.

19. Braden's talk and analysis of films; Stan Plagenhoef's comments--practical.

20. Vic Braden's. Interesting presentation--good overall analysis.

21. Glick--tennis elbow; Plagenhoef; Waddell--badminton; Braden--tennis teaching clinic.

22. Vic Braden, Dr. Glick, Joanne Taylor, Stan Plagenhoef--gave information I can use.

23. The sessions which showed skilled performers at 400 frames/sec., Vic Braden, Barbara Gowitzke, David Waddell, Donna Phillips.

24. John Lynch--racketball teaching. Got to the basics. Allowed questions throughout.

25. Glick, Murphy, Plagenhoef. My interest and thoroughness in presentation.

26. Vic Braden's teaching clinic because that is the way I hope people all over the country will start teaching the game by utilizing everything we know from all the disciplines. And most importantly, in my mind at least, the stress on the idea that tennis should be fun for the recreational player. It is difficult to name most important without mentioning a few others that were right up there also and they are: Joanne Taylor's presentation and Drs. Baller and Glick. Films and audio-visuals in all presentations were most helpful.

27. Vic Braden's tennis clinic. Practical application of technique.

28. Plagenhoef. He was truthful.

Figure 1c

Question 13: Which session was least beneficial for you? Why?

1. Many of the scientific presentations were meaningless to me. Because I could not apply the findings (as they were presented) to my coaching.

2. Too many of the papers had no definite or practical conclusions.

3. Scientific presentations, generally. They do not speak to me--generally I cannot use what they are doing. (Plagenhoef summed up my feeling extremely well--he was great.)

4. Physiology presentation.

5. Biomechanical research--never really bridged the gap into the practical situation. Tell how to bridge, not just research results. Big names did this better in clinics. Need interpretion and application. It would be interesting to take a researcher and a teacher/coach who have worked before hand-on findings and application--and have both present in one session. Plagenhoef has some viable observations and comments.

6. Some papers in research on the psycho-social area. Sociology is not my interest area.

7. Murphy--biomechanical aspects of tennis. Feel he did not speak to level of group and did not appear as organized as the others.

8. Murphy--biomechanical aspects of tennis. Too elementary seemingly undocumented; also, somewhat disjointed presentation. Not really geared to this audience.

9. Research paper presentation, research lab tour. I am at the secondary level and not involved in research.

10. Joanne Taylor's fitness session. Too elementary for higher education professors in physical education. However, concept emphasis (rachet teachers do not use warmups) was accurate but her session was too long. It would have been much better to have given Vic Braden that time.

11. Some of the scientific papers. Scientific jargon and statistics were somewhat nebulous--outcomes were the most useful.

12. Psychosociology. Did not seem as applicable, nor, as interesting to me.

13. Taylor, Ramey-Ford. Elementary and trite ideas.

14. Joanne Taylor--conditioning warmups. Very broad, general--not substantiated statements. Many of these ideas were first learned as a freshman in college.

15. Conditioning by Joanne Taylor. Because she talked "down" to her audience.

16. Conditioning (Thurs.); too basic.

17. Abstracts. Some were not "my cup of tea."

18. Joan Ramey-Ford. Tone of talk, approach.

19. Session on warmup--flexibility, etc. Presented at too low a level for participates. Ramey-Ford--inaccurate information.

20. Sarah Smith, Pat Keating. Hard to interpret data in time allowed.

21. Joan Ramey-Ford--nothing new or in-depth was presented, poor teaching approach. Lab tours.

22. Lab tours--except for telemetry. Not as practical an application.

23. Baller.

24. In-depth analyses of the tennis serve by Joan Ramey-Ford. Technique outdated and certainly not an in-depth analysis. Would be nice to get USPTA and USTA involved.

25. Certain highly technical scientific presentations with no practical application in the coaching field.

26. Thursday night. Too long a day.

Figure 1d

Comments:

1. Jack--thank you so much for making the symposium possible. I know you must have put in a tremendous amount of time and effort to make the conference such a success. I only wish more people had been able to reap the benefits of all your efforts.

   I will be the Director of Racquet Sports next year at Georgetown University (in addition to the women's tennis coach) so the idea of a Symposium on Racquet Sports was very exciting to me. I would not have minded longer and more detailed clinics in each of the four racquet sports--but not at the expense of eliminating other topics.

   The scientific presentations (some, that is) were vague to me but as we concluded in the panel discussion..."Bridging the Gap" is a difficult task.

   "I only hope you have the time, energy, and money (which I know is critical) to do this again next year. It was great!"

2. Leave the evenings open for social hours so that the participants have more time to share their ideas individually.

3. "Jack--thanks very much for an excellent program and for including me."

4. Need a film room where film can be shown perhaps simultaneously with presentations as well as during some free time.

   Need some participation by some if not all the people in selected types of situations.

   More handouts might be appropriate and appreciated by both the scientific presenters and the coaches.

   Tapes need to be made available. I know an attempt was made in this area, but at least one person who attended the symposium got it all on tapes. Fortunately, I was able to get the tapes I wanted from her. If I had not been able to get the tapes I wanted, I would have been disappointed.

   You perhaps have no control over this, but I was pleasantly surprised that so few people attending here smoked. As you get more people in the meetings you may want to think through some rules, such as, no smoking during meetings, or perhaps have a smoking section. If you do anything in this regard, check the direction smoke escapes in each room.

   Need more demonstration work with beginners. This brings out the proof or fallacy of what the presenters are telling us. Seeing a master teacher at work is worthwhile also.

5. Too cold! Perhaps a schedule which allows for some recreational activities. Thursday's session was too long. Either extend the number of days of clinic or have fewer presentations.

   It would be good to know in advance if there will be opportunities to participate. Very good symposium. I enjoyed it and learned a lot.

   I would enjoy "too much time" with the "big names" so that they never have to be cut off. I do not think that anyone would mind if a lecture fell 15 minutes short and so they had a 1/2 hour break rather than a 15 minute break.

   Thanks much for all your hard work. Everyone here at Illinois was great. Keep up the good work.

6. (a) Allow a recreation period for people--for jogging or racquets.
   (b) Preconference publicity was not clear as to whether this was a participation conference--did not know what type of clothes to bring.
   (c) Have big names--Vic Murphey, Joan Ramey-Ford available for chatting during entire conference.

   It would be interesting to take a researcher and a teacher/coach who have worked beforehand on findings and application--and have both present in one session.

   Plagenhoef has some viable observations and comments.

   Great cookout--good bar! Need recreational facilities free.

7. Would enjoy a participation part (clinic) so we could try out some of the sports or work on spins, etc.

   The first day (Thursday) was too long with the night session and many short research papers. Might have been better to have only 3 night speakers with at least 15 minutes of time apiece plus questions instead of 5-6 people. I was then saturated. Friday's sessions seemed just right and the cookout was fun.

   The interaction between the speakers and participants was very good and the social aspects were satisfactory. I enjoyed the mental stimulation of both of these groups.

8. I think it would have been very beneficial to be able to participate during the teaching clinics. It would have been good to be able to try the ideas that were given to us by the experts.

   Also, it would have been nice to have some badminton, squash and racketball courts available for recreational play, or at least since we did not participate in the teaching clinic, to be able to try out the teaching techniques given to us.

   Too much on Thursday--should have provided more tree time--also had we started later, it might not have seemed so long.

Steak cookout a good idea.

Good variety of speakers--good also to have research reported--should have listed names of all presenters on program.

Symposium was a good idea--I enjoyed it.

9. Overall the conference was excellent. However, I was disappointed that there was no "participation" session. I realize that with the size of the group and the logistics involved that there are some problems but I think if another symposium were held it should be tried. It was clear that several teaching clinicians were restricted (i.e., Murphy) in their presentation because of the lecture format. A lecture session followed by a workshop/participation session would be desirable. Or at least have the clinician out on a real court where he or she could do more demonstration. I was expecting a little more on teaching techniques or tips (i.e., correcting common errors and/or large group instruction) rather than so much emphasis on biomechanics. That approach was interesting and informative (i.e., pronation in badminton) but was highly specific to expert players. How about more practical applications for the teacher who works with the beginning/intermediate player? The "mike" system was also cumbersome for the clinician. Give people like Murphy, Braden, and Waddell more time for their presentations.

I am not so sure that this symposium should be held every year. There are so many competing conventions and conferences, but having it in the summer helps but finances become a problem. Also, having it every year *may* water down the quality of the presentations. I would recommend every other year. Also, put a bigger, more noticeable advertisement in the *JOPER*.

Stanley Plagenhoef was, although biased, quite possibly instructive. We should focus more on the beginning/intermediate level players. What teaching methods produce the best results or promote positive teaching behaviors.

10. Overall, I was most impressed with the high-powered approach to the study of racquet sports. It is always difficult to interest and meet the needs of everyone all the time. You might consider offering two choices at certain times which might reach more people (i.e., scientific papers or how to improve your backhand). More participatory activities could be considered. Many of the symposium attendees would have liked to try some of the ideas proposed.

Also, a person of Chet Murphy's calibur should have had more than an hour. He barely got started and then he had to quit.

Recruit exhibitors to display various equipment, books, ideas, etc. Charge them a fee for exhibiting which can help in defraying your cost.

11. As usual for the University of Illinois, the conference was well organized, friendly, and interesting. By far the best set-up for a conference I have ever encountered. A wealth of material mailed to keep me informed of times, places, events. Always ready to help, especially the speakers and making contacts between interested persons.

12. Early and additional publicity might aid in its promotion for next year. Commercial displays might aid in raising additional funds. Perhaps reorganize our presentations to a more equal offering of both scientific and practical areas. Although, I feel there were many this year of both varieties.

13. Much too much time on introduction to most topics and not enough material covered in clinic, i.e., Waddell should not need 1½ hours to show there is pronation in a badminton smash when this could have been adequately covered in 15 minutes, or I guess, by Barbara G. Waddell in 12 minutes. He really did not add anything much to this when there are so many important techniques the coaches and researchers should be accustomed to in badminton.

    I would like to see at least 5 minutes discussion allowed following the papers as this is where the real exchange of information occurs in many cases.

    MD's did not give information on technique, etc. and less probable than Plagenhoef on tennis elbow in terms of play, technique, etc. A few case studies is not really data on the injury or rehabilitation. I thought they were good talks on their subject, but maybe not for such a conference as this.

14. Too Damn cold! Thursday's session was too long. 8 AM - 10:30 PM cannot hold my attention and have a desire to come again the next day. Overnight accomodations at Illini Tower were very nice. Only wish I knew to bring TV or radio. Certainly was a thought provoking 3 days. Also, by the information on the brochure I would have believed there to be participation--this needed to be clarified.

15. Possibly hold teaching clinics on court. Hold the scientific presentations during the day with major talks (i.e., Braden, Glick, Waddell) for the evening sessions.

16. The symposium met my expectation. However, I feel that too much emphasis was given to the abstracts. Even though the idea is to "bridge the gap" thephysiology and biomechanics, in my opinion, was not useful to me. Perhaps (in the future) if the emphasis is on all the research then maybe only researchers should be present and not teachers (coaches, etc...)

    More sessions on squash, badminton, racquetball would round out the symposium. A better scope of information available to the participants in these areas would be helpful.

Dr. Chet Murphy definitely needed more time. This gentleman has much knowledge and information and only 1 hour plus was a definite limitation! He needed to be scheduled for more time. A person of this caliber and experience should be given the necessary time to cover the field and important information.

17. Enjoyed the seminar.

18. Would appreciate knowing whether or not people will be actively participating in on-court exercises--want to know what equipment to bring. Might consider scheduling brief stretch and exercise periods to work off some of the good food--keep people from falling asleep after lunch.

Publicity was negligible--better PR might help the conference to be solvent next year.

19. Many thanks for all of the efforts that went into this symposium--it was well worth my time and money--keep up the good work!

20. Too much sitting! The mind can absorb only what the seat can endure. Need to combine a practical approach with some activity. Why no real demonstrations (except for badminton)?

Some talks were excellent--squash, racketball. Too heavy on emphasis on tennis--although this may be the most popular of the 4 sports. I came primarily for the other 3 racquet sports. As a badminton "specialist," I found the main speaker interesting, but redundant and covering too few strokes. This was most disappointing.

The physicians were great! Fascinating! Some scientific presentations were very boring. These should be more selective. The food and lodging were excellent!

21. Excellent! I certainly hope there is another such meeting each year.

22. This symposium was very helpful to me. The tendency is for people to expect more the following year--good luck, Jack, you have a tough act to follow! June is a good time of year for symposium.

23. Next year--sessions on coaching tennis on a team basis, sessions on dealing with pressure, sessions on concentration techniques, informal meetings of people with like interests with time set aside, for example, team coaches, researchers, physical education teachers to discuss common interests, specific first aid session relative to injuries in racquet sports, e.g., muscle pulls, leg cramps.